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# Evaluation of Research Vessel and Individual Transferable Quota (ITQ) Survey Data as Abundance Indices for Pollock

# Évaluation des données de relevés de navire de recherche et de quota individuel transférable (QIT) comme indices d'abondance de la goberge

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## ABSTRACT

Recent pollock (*Pollachius virens)* assessments have been based on commercial fishery catch rates. As part of the Pollock Framework assessment, we evaluated the utility of fishery-independent data sources, such as summer research vessel (RV) and joint government/industry (ITQ) surveys, to develop abundance indices. Strong year effects confounded interpretation of age-disaggregated abundance indices based on data from summer RV groundfish surveys. Only very strong or weak year-classes were detectable on a year by year basis. However, when the age specific indices were summed over a year-class and compared with those obtained from the commercial catch rate information, there was some concurrence on the relative strength of year-classes. There was also broad scale agreement between trends in survey abundance and population biomass from the VPA, although survey areas do not precisely match. There was good agreement between catch rates from the RV and ITQ surveys for the proposed western management area 4Xopqrs, however it proved difficult to identify year-classes in the ITQ survey data. We concluded that the RV survey indices should be considered as an age-aggregated index in the continued development of the Framework Assessment for this species and that the ITQ survey results could be reconsidered at a later date when the survey series is longer.



## RÉSUMÉ

Les récentes évaluations de l'abondance de la goberge (*Pollachius virens)* reposaient sur les taux de capture réalisés dans le cadre des pêches commerciales. Au titre de l'examen du cadre d'évaluation de l'espèce, nous avons évalué l'utilité de sources de données indépendantes de la pêche, comme les relevés de navire de recherche effectués en été et les relevés concertés gouvernement-industrie, comme fondement d'indices d'abondance. Des effets marqués de l'année ont affecté l'interprétation des indices d'abondance désagrégés à l'âge tirés des données des relevés de NR visant le poisson de fond en été. Seules les classes d'âge très fortes ou faibles étaient décelables d'une année à l'autre. Toutefois, lorsque les indices par âge d'une classe d'âge étaient additionnés et le résultat comparé à celui tiré des données sur les taux de capture commerciale, on a remarqué un certain accord dans l'abondance relative des classes d'âge. On a aussi vu un accord à grande échelle entre les tendances dans l'abondance établie par relevés et la biomasse de la population obtenue par APV, quoique les secteurs de relevé ne soient pas exactement les mêmes. On a observé un bon niveau d'accord entre les taux de capture obtenus lors des relevés de NR et des relevés QIT pour les sous-divisions de gestion de l'ouest 4Xopqrs, mais il s'est révélé difficile d'identifier les classes d'âge dans les données des relevés QIT. Nous tirons la conclusion que les indices des relevés de NR devraient être considérés comme un indice agrégé par âge aux fins du développement du cadre d'évaluation de la goberge et que les résultats des relevés QIT pourraient être examinés de nouveau lorsque la série de relevés sera plus longue.

## INTRODUCTION

Recent pollock (*Pollachius virens*) assessments in the Canadian Maritimes have been based on commercial fishery catch rates. Many researchers have argued for the inclusion of fishery independent data in stock assessments since these data would not be subject to changes in fishing patterns such as the redistribution of effort or technological advances which result in changes to fishing efficiency. Occasionally, data from research vessel surveys have been used to calibrate the population model in the assessment and to provide abundance estimates during years of pronounced change in the pollock fishery. For example, in the 1990 Assessment (Annand et al. 1990), it was decided that changes in fishery regulations such as trip limits complicated the interpretation of catch rates and that the commercial data was not a representative abundance index. However, research survey data such as pollock abundance from the annual research vessel (RV) summer groundfish surveys conducted by the Department of Fisheries and Oceans (DFO) are problematic. In the 1991 assessment, problems associated with these data were summarized as, 'in general, the survey exhibits pronounced year effects making it difficult to determine year-class strength and short-term changes in abundance (Annand and Beanlands 1992). The recent trend in pollock assessments has been to not use the information from RV surveys.

Within the context of the Pollock Framework Assessment, our purpose here is to re-evaluate the utility of fishery-independent surveys in the estimation of abundance indices. In the first meeting of this Framework Assessment, the stock was split into two areas roughly corresponding to the NAFO areas 4Xopqrs5YZc and 4VWXmn based on an evaluation of pollock growth rates, fishery distribution, ichthyoplankton, meristics and morphometrics and tagging information (Fig. 1, Neilson et al. 2003a). Pollock from NAFO areas 4Xmn were grouped with those from the eastern Scotian Shelf due to similar growth rates. Unless otherwise noted, the aggregations of data presented here follow those conventions.

## FISHERY-INDEPENDENT SURVEYS

The RV summer groundfish surveys follow a stratified random design with strata defined by depth (50, 100 and 200 fathoms). Trawl locations within each strata are randomly selected prior to each survey. The western Scotian Shelf and Bay of Fundy are generally sampled in early July. A Western IIA trawl is towed for 1/2 hour, approximately 1.75 nautical miles. Catch is then adjusted to this standard distance if the trawl distance differed from the standard. Analysis software is available to provide estimates of stratified mean catch per tow at age, using available age-length keys. The survey series started in 1970 and continues.

In addition, the Department conducts a depth-stratified random survey on Georges Bank, covering the entire Bank. Considering the pollock stock area includes 5Zc (the Canadian portion of Georges Bank) an area not covered by the annual summer survey, this survey is also of interest. The Georges Bank RV survey (1986-present) generally occurs in February, but occasionally extended into March during earlier years.

Industry and the Department established an annual survey (referred to here as the ITQ survey, reflecting the industry group responsible) in 4X in 1995. The survey was initially established primarily to obtain information on the distribution and abundance of cod, haddock and winter flounder (O'Boyle et al. 1995). The ITQ survey complements the DFO summer survey as it is conducted during the same time each year, and covers an area of 4X further inshore than surveyed in the DFO design. ITQ survey blocks were based on DFO research vessel survey strata which were subsequently subdivided into minor blocks of 2.5 minutes latitude by 2 minutes longitude. Tows are standardized to a distance of one nautical mile, and can vary in duration. One hundred and eighty-six unique stations have been occupied during the ITQ survey time series. Of these, 184 have been sampled consistently over the years. While the survey commenced in 1995, that year is not included here, since 48 stations were added in 1996. Each of the three vessels fished a particular geographic zone within the total survey area. Within each geographic zone, the skippers

selected the sampling stations. The gear employed was a rockhopper design (280 balloon trawl with 19 mm codend liner).

## RESEARCH VESSEL RESULTS – SUMMER SURVEYS

*Distribution*

The areas covered by the DFO summer surveys include much of the pollock fishery and in general, patterns of pollock distribution are similar between the two data sets. The pollock fishery is concentrated off southwestern Nova Scotia and in the Bay of Fundy (NAFO areas 4X5Y) during the summer months (Fig. 2). Many pollock are also caught in this region during the DFO RV survey (Fig. 3). The fishery is also concentrated along the northeast edge of the Scotian Shelf, however, fewer pollock have been caught in this area (4V) over the past five years (Fig. 2). This local decrease in pollock was noted in the survey data as well. The survey data provides information on pollock abundance in areas that are now closed to the fishery, such as much of the eastern Scotian Shelf. Coverage by the commercial data also extends further inshore than does the DFO RV survey. There is a consistent component of the fishery on the Canadian portion of Georges Bank (5Zc) which is not sampled by the DFO summer RV or by the ITQ surveys, but is sampled in the February DFO Georges Bank survey.

The percentage of years during which pollock were caught in particular RV strata is a measure of pollock occurrence. The proposed western management unit includes 14 strata. Pollock were consistently caught in eight of these western strata; pollock were caught in over 90% of the annual surveys from 1970 to 2002 in these eight western strata (Fig. 4). By contrast, the eastern management unit includes 30 strata, pollock were consistently caught in only four of the eastern strata (Fig. 4). Stratified mean weight per tow by stratum is a measure of pollock abundance in particular RV strata. These data are presented in Table 1 for the proposed western management area (Southwest Nova and the Bay of Fundy, 4Xopqrs) and in Table 2 for the central

and eastern Scotian Shelf (4VWXmn). When both pollock frequency of occurrence and abundance are considered, it is possible to identify a subset of survey strata of preferred pollock habitat. For Div. 4X, the seven strata we selected from the western region included 476, 481-2, 484-5 and 490-1, and are referred to here as key pollock strata.

*Abundance*

Inter-annual variability in pollock biomass caught by RV surveys confounds interpretation of year-class strength. Large inter-annual changes in annual pollock catches are evident in both 4Xopqrs and 4VW (Fig. 5). Stratified mean biomass from 4Xmn has followed trends similar to stratified mean biomass from 4VW since the late 1980s. To assess whether strong or weak year-classes could be identified and tracked in the surveys, we show the stratified mean number caught per tow at age for the proposed western management unit (Fig. 6). Strong year effects dominate the surveys. However when the data are presented as a proportion of total annual catch, strong year-classes such as the 1979 and 1992 cohorts are more noticeable (Fig. 7). By comparison, the 1979 cohort is prominent in the age-disaggregated indices from the commercial fishery in Divs. 4X and 5Zc (TC 2-3 otter trawlers, updated using the approach of Neilson et al. 1999, Fig. 8). The 1979 year-class has been consistently identified in previous assessments as the strongest year-class in the population models. Weaker year-classes also show sequential low points in the commercial data.

Age disaggregated indices expressed as a proportion of the total catch in 4Xopqrs from the RV summer survey are shown in Fig. 9. The 1979 year-class does not appear consistently larger than the indices at age observed in other surveys. Cohort tracking was not improved when data were selected from key pollock strata from the proposed western management area (Fig. 10). We decided not to pursue the use of the key strata further since there was no improvement when we limited the analysis to areas with consistent pollock catches. Research vessel survey data also appear to track weak year-classes well. In the western Scotian Shelf and Bay of Fundy (4Xopqrs)

the 1977 cohort stands out as weaker than other years (Fig. 9). This finding is consistent with the last pollock assessment that included information on year-class strength from the 1970s, although the conclusion was made for the older 4VWX5Zc management unit. Neilson et al. (1998) indicated that the 1977 year-class was the weakest in the series of recruits from 1974 to 1995.

The 1979 year-class is notable in the bubble plots for the central and eastern Scotian Shelf (Fig. 11). The largest catch of age 3 pollock observed in the survey series were from this year-class and the cohort can be tracked through the subsequent years. The 1977 year-class appears weak in this plot as well.

We summed the indices at age for the RV series in the proposed western management unit and ranked the year-classes. Stratified mean catch per tow from the RV survey was adjusted relative to the proportion of annual catch before the catch was integrated along cohorts and ranked. We then performed the same summation of indices from the age disaggregated commercial CPUE data, and compared the two sets of rankings. We expected that if the two sets of indices are interpreting the year-class strength in a consistent manner, then the plotted values in Fig. 12 should be on or near the line representing a slope of one. Integrated catch rates from the commercial fishery and RV surveys produced similar ranks of year-class strength (Spearman's rank correlation, rho=0.771, p=0.000, n = 16). In 4 of 16 instances year-classes were identically ranked by the two sets of abundance indices. In 3 of 16 instances, they were within one. In general, the best agreements were noted with stronger year-classes. Similar analyses were not conducted for the eastern management unit (4VWXmn) because of large changes in fishing effort in this region due to fishery closures.

*Environmental modifiers of RV Abundance Indices*

Hydroacoustic investigations of pollock (Neilson et al. 2003b) indicate that pollock aggregations tended to more available to that type of gear at night. To investigate whether different

catch rates were associated with different times of day, we split the survey data into 6 4-h blocks and conducted a one-way analysis of variance on the natural log transformed data. While there was a tendency for lower catch rates to be observed at night (Fig. 13), the differences were not significant ($F=1.587$, $p=0.160$, $df=5$). Similarly, a lack of diel effects was noted in trawl catch rates by Neilson et al. (2003b). Although hydroacoustic information indicated that pollock were more densely aggregated at night, large catches were obtained during both day and night trawls (Neilson et al 2003b).

Using the approaches of Perry and Smith (1994), we investigated associations of pollock catches with bottom water temperature. To determine if temperature preferences were related to fish size, we conducted the analyses for fish >40 cm and those less than or equal to 40 cm. This length was chosen because is close to both the length associated with differences in habitat use between large and small fish (Clay et al. 1989), and associated with gonad development and sexual maturity (Nelison et al 2003b, Trippel et al. 1997). Examples of cumulative frequency distribution plots of both temperature and pollock occurrence in 4X and 4VW are shown in Fig. 14. Most pollock caught in RV surveys were at temperatures of at least 4 °C. Larger fish (>40 cm) were generally found in warmer water than smaller fish. Water temperatures were cooler in 4VW with half of the area having temperature <4 °C. There was no evidence for a significant association between temperature and pollock abundance in 4X. In 4VW, there were significant associations between numbers caught and temperature during the period 1989-2000/2001. Mean temperatures in 4VW were consistently below the average for the 1970-2002 period during these years (Fig. 15, Table 3). The results indicate that bottom temperature may have an effect on the survey abundance indices in 4VW during relatively cold years. On the other hand, temperatures were never cold enough to have an effect in 4X

## GEORGES BANK SURVEY - RESULTS

The trend in mean catch per tow from the Georges Bank survey indicates strong inter-annual variations in pollock abundance including seven years when almost no pollock were caught (Fig. 16). Since 1994, the Canadian portion of Georges Bank has been closed from 1 January to 31 May for all groundfish vessels to minimise disturbance to spawning cod and haddock (DFO, 2002). Thus, low catches in the RV survey from 1994-2001 cannot be compared to other data sources such as commercial catch rates. Further, the Canadian proportion of pollock catch in the Georges Bank survey has high variability relative to the rest of the Georges Bank (Fig. 17). Therefore, we did not pursue further investigation of abundance data from this survey.

## ITQ SURVEY – RESULTS

*Distribution*

The ITQ survey area within NAFO Div. 4X extends from the inshore to 200 fathoms depth, and is divided regionally among the three commercial fishing vessels (Fig. 18). There are annual differences in the distribution of pollock catch but, in general, the Bay of Fundy region reported the highest catches, and there were numerous stations where no pollock were caught in Southwest Nova and the Scotian Shelf region (Fig. 19). Locations with consistent pollock catches can be identified within the ITQ fixed-station design; several stations in the Scotian Shelf region had pollock in each year of the survey. There was no trend in the distributional index (% non-zero sets) over the time series. The percentage of non-zero sets varied between 40 and 63% (Table 4).

*Abundance*

Mean catches in Southwest Nova and in the Bay of Fundy regions show a similar increasing trend from 1998 to a maximum in 2001, then in 2002 return to low levels similar to 1998

(Fig. 20). The catch rate trend for these vessels parallels catch rates for RV surveys in NAFO Division 4Xopqrs, which includes much of the area surveyed by these two vessels. Catch rates from the Scotian Shelf were lower than for the other two regions and did not follow the same increasing trend from 1998-2001. Ninety percent of these data were excluded from further analysis when we excluded 4Xmn for comparison with RV data.

Length frequency distributions of pollock caught in ITQ surveys were similar to those for pollock caught in DFO RV surveys for 1996-2002, with the exception of 1999 (Fig. 21). Although, the ITQ survey covers waters further inshore, and pollock spend a considerable portion of the first two years of their lives in coastal habitat, the ITQ did not catch smaller pollock than the RV survey (Fig. 21). Habitat used by juvenile pollock includes intertidal areas (Rangeley and Kramer 1995) which are much further inshore than the ITQ sampling stations, thus the distribution of ITQ and RV survey area may not be sufficiently different to catch a different age composition of pollock.

Bubble plots of age specific indices were derived from the application of the summer RV age-length keys to the length frequency distribution information from the ITQ surveys (Fig. 22). Year-classes are not evident in bubble plot based on age-disaggregated catch in the ITQ survey. Unlike, the RV data we cannot identify known strong (1979) or weak (1977) year-classes and evaluate whether these cohorts can be tracked through the survey data because the time series is too short. Since, it is appropriate to consider the youngest age available to the ITQ survey to be age 2 (age 1 fish are thought to in nearshore areas and would not consistently be available), only the 1994 cohort can be tracked from age 2 to age 8. Thus, the ITQ survey should be reconsidered when the survey series is longer.

The occurrence of very large catches confounds interpretation of these data. Much of the catch was concentrated in a few sets, with under 10% of the sets accounting for 75% of the overall catch in 6 of the years (Table 4). These large sets account for much of the signal which may explain inter-annual variability in total catch and the lack of a coherent signal in cohort strengths.

Furthermore, these large sets do not occur in the same locations each year. If these sets are not representative of the overall age structure, i.e. the pollock are aggregating by age, then the catch at age for this survey will not reflect the population either.

## CONCLUSIONS AND RECOMMENDATIONS

The use of the summer RV surveys as age-disaggregated indices of abundance is problematic. Year effects are predominant, and only the strongest of recent year-classes were detectable on a year by year basis. This was the case even when we selected a subset of strata that had historically been associated with consistent occurrence and high catch rates of pollock.

However, when the age specific indices were summed over a year-class and compared with those obtained from the commercial catch rate information, there was some concurrence in the interpretation of relative year-class strength. The comparison between DFO summer research vessel and commercial catch rates for NAFO Divisions 4Xopqrs illustrated that, although year effects were more pronounced in the RV data, both indices have shown a declining trend since the early 1990s (Fig. 23). As a further comparison, we updated the virtual population analysis of Neilson et al. (1999) and compared trends in population abundance with trends in abundance indicated from the RV surveys. While the areas compared did not match precisely (the VPA covers Div 4X and 5Zc whereas the survey indices were provided for 4X), there does seem to be some broad scale agreement between trends in the surveys and population biomass from the VPA (Fig. 24). Given this, we conclude that the survey indices should be considered as an age-aggregated index in the continued development of the Framework Assessment for this species.

Regarding the use of the ITQ survey information, we are less optimistic. The age composition in the most recent years (2000-2002) seems to be stable, but other indices (RV, commercial CPUE) suggest strong recent recruitment. On the other hand, the trend in catch per tow derived from the two westernmost zones in the ITQ survey show patterns that match RV survey

data well. However, the duration of this time series is short, and it may be that the ITQ survey will demonstrate further utility for pollock abundance indices as additional data become available.

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Table 1. Mean weight of pollock catch from each stratum of 4Xopqrs caught during RV summer surveys.

| Strata | 474 | 476 | 480 | 481 | 482 | 483 | 484 | 485 | 490 | 491 | 492 | 493 | 494 | 495 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1970** | 0 | 7.66 | 3.89 | 0 | 0.97 | 0 | 0 | 103.03 | 8.20 | 0 | 0.00 | 60.58 | 0 | 0 |
| **1971** | 0.49 | 0 | 2.43 | 9.04 | 5.53 | 0 | 1.64 | 0 | 0 | 2.66 | 0.00 | 0.00 | 0 | 0 |
| **1972** | 0 | 0 | 0.95 | 0 | 0.92 | 3.40 | 6.16 | 94.16 | 0 | 102.14 | 25.70 | 0 | 0 | 12.79 |
| **1973** | 0 | 6.81 | 2.46 | 15.63 | 0 | 0 | 3.25 | 84.34 | 0 | 20.38 | 5.89 | 5.15 | 0 | 0 |
| **1974** | 0 | 46.86 | 0 | 5.45 | 0 | 0 | 6.16 | 4.43 | 16.31 | 4.57 | 13.56 | 0 | 2.08 | 8.24 |
| **1975** | 0 | 23.54 | 0 | 0 | 0 | 0 | 6.10 | 2.02 | 5.36 | 3.56 | 8.53 | 1.54 | 4.14 | 3.15 |
| **1976** | 0 | 3.28 | 0.46 | 0.59 | 0.65 | 3.89 | 67.32 | 4.56 | 18.28 | 11.24 | 10.51 | 2.63 | 13.01 | 0 |
| **1977** | 0 | 53.54 | 44.22 | 8.39 | 2.55 | 1.46 | 12.22 | 418.85 | 6.61 | 6.85 | 42.79 | 5.14 | 0 | 0 |
| **1978** | 0 | 10.50 | 0.36 | 5.05 | 4.08 | 0.00 | 1.46 | 9.31 | 42.22 | 0 | 14.49 | 0 | 0 | 0 |
| **1979** | 0 | 0 | 0 | 0 | 53.38 | 1.17 | 42.41 | 56.47 | 5.47 | 220.92 | 0.00 | 2.75 | 0 | 6.92 |
| **1980** | 2.06 | 8.17 | 2.59 | 8.99 | 4.97 | 3.49 | 0.76 | 147.45 | 6.73 | 8.77 | 0.00 | 5.59 | 0 | 2.33 |
| **1981** | 0 | 0 | 0 | 5.59 | 27.60 | 0.00 | 57.62 | 17.18 | 83.42 | 1.75 | 2.33 | 0 | 0 | 5.83 |
| **1982** | 0 | 0 | 0.51 | 10.55 | 8.41 | 2.57 | 1.03 | 146.91 | 11.35 | 4.03 | 58.48 | 23.38 | 0 | 0 |
| **1983** | 0 | 26.68 | 10.21 | 7.53 | 2.52 | 2.57 | 0 | 6.75 | 3.09 | 8.45 | 4.46 | 8.10 | 0 | 0 |
| **1984** | | 212.06 | 0 | 1.80 | 7.44 | 7.72 | 14.41 | 61.98 | 0 | 16.47 | 4.38 | 0 | 0 | 0 |
| **1985** | 0 | 0 | 11.28 | 0.46 | 2.43 | 1.94 | 13.61 | 55.17 | 457.92 | 22.49 | 1.62 | 198.35 | 1.46 | 1.38 |
| **1986** | 3.75 | 53.53 | 9.55 | 27.60 | 5.66 | 0 | 11.32 | 115.59 | 10.47 | 134.51 | 38.24 | 2.92 | 0 | 0 |
| **1987** | 1.64 | 5.30 | 48.90 | 1.53 | 18.23 | 6.02 | 20.77 | 57.82 | 1.38 | 388.09 | 18.22 | 22.65 | 0 | 0 |
| **1988** | 0 | 99.17 | 0.22 | 6.31 | 16.00 | 4.63 | 36.01 | 600.25 | 4.90 | 17.74 | 29.68 | 0 | 0 | 0 |
| **1989** | 0 | 17.29 | 5.41 | 1.94 | 168.80 | 0 | 2.99 | 113.42 | 4.26 | 35.52 | 2.32 | 0 | 0 | 6.02 |
| **1990** | 0 | 419.42 | 8.28 | 185.74 | 11.61 | 56.64 | 21.18 | 34.45 | 36.06 | 16.09 | 11.32 | 0.31 | 0 | 0 |
| **1991** | 0 | 7.32 | 7.79 | 58.62 | 83.63 | 146.09 | 22.41 | 13.42 | 53.63 | 13.65 | 4.91 | 3.24 | 0 | 0 |
| **1992** | 0 | 5.10 | 5.57 | 3.04 | 33.48 | 4.18 | 36.33 | 6.02 | 4.38 | 15.23 | 24.86 | 2.27 | 0 | 0 |
| **1993** | 0 | 16.47 | 1.07 | 125.26 | 15.48 | 5.66 | 7.86 | 114.57 | 4.44 | 26.96 | 1.94 | 0 | 0 | 0 |
| **1994** | 1.32 | 75.06 | 5.27 | 4.17 | 8.27 | 0 | 1.00 | 37.28 | 8.42 | 38.65 | 7.55 | 24.42 | 0 | 1.00 |
| **1995** | 0 | 19.96 | 18.27 | 5.03 | 12.45 | 0 | 39.22 | 12.37 | 1.72 | 14.28 | 8.73 | 0 | 0 | 1.86 |
| **1996** | 3.68 | 2.63 | 2.35 | 2.93 | 9.06 | 0 | 352.93 | 11.64 | 6.80 | 24.18 | 16.90 | 0 | 0 | 0.16 |
| **1997** | 0.22 | 11.07 | 1.49 | 2.09 | 8.67 | 12.88 | 7.73 | 26.36 | 0 | 19.70 | 4.94 | 0 | 0 | 6.92 |
| **1998** | 0 | 5.77 | 0.20 | 0.77 | 5.45 | 0.76 | 13.69 | 11.90 | 1.15 | 13.33 | 4.25 | 0 | 0.09 | 3.08 |
| **1999** | 0.85 | 0.46 | 13.22 | 2.21 | 4.69 | 0 | 11.54 | 10.37 | 0 | 6.91 | 3.42 | 0 | 2.97 | 1.38 |
| **2000** | 0 | 0.26 | 1.48 | 0.40 | 13.46 | 1.33 | 0.35 | 22.66 | 1.18 | 13.57 | 12.98 | 0.16 | 0.44 | 0.43 |
| **2001** | 0 | 0.97 | 0.11 | 41.80 | 8.94 | 0.56 | 28.55 | 5.19 | 22.73 | 19.65 | 9.72 | 0 | 0.34 | 0.19 |
| **2002** | 1.54 | 1.56 | 0.03 | 0.74 | 3.91 | 16.92 | 9.39 | 9.31 | 0.02 | 23.27 | 12.18 | 0 | 0.05 | 0.85 |
| **Total** | 15.54 | 1140.41 | 208.58 | 549.26 | 549.24 | 283.89 | 857.42 | 2415.20 | 826.47 | 1255.62 | 404.90 | 369.14 | 24.59 | 62.51 |
| **Mean** | 0.49 | 34.56 | 6.32 | 16.64 | 16.64 | 8.60 | 25.98 | 73.19 | 25.04 | 38.05 | 12.27 | 11.19 | 0.75 | 1.89 |
| **CV** | 209.62 | 233.11 | 179.59 | 232.32 | 192.95 | 310.21 | 235.32 | 168.52 | 318.57 | 201.84 | 111.05 | 318.93 | 321.70 | 165.08 |

Table 2. Mean weight of pollock catch from each stratum of 4VWXmn caught during RV summer surveys.

| | 440 | 441 | 442 | 443 | 444 | 445 | 446 | 447 | 448 | 449 | 450 | 451 | 452 | 453 | 454 | 455 | 456 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1970** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.19 |
| **1971** | 0 | 2.92 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2.28 | 0 | 0 | 0 | 0.82 |
| **1972** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.46 | 0 | 0.34 | 0 | 0 |
| **1973** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.18 |
| **1974** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **1975** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0.73 | 0 | 0 | 0 | 0 | 0 | 0 |
| **1976** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.55 | 0 | 0 | 0 | 0 | 0 |
| **1977** | 0 | 0 | 0 | 0 | 0.17 | 0 | 0.34 | 0 | 0 | 0 | 0 | 2.43 | 0.55 | 0.69 | 0 | 0 | 0.86 |
| **1978** | 0 | 0.31 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13.13 | 1.46 | 0 | 0.39 | 0 | 0 |
| **1979** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.61 | 0 | 5.83 | 2.33 | 66.76 | 13.90 | 0 | 0 | 0 | 0 |
| **1980** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **1981** | 0 | 6.71 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10.29 | 11.08 | 0 | 0 | 0 | 0.59 | 0 |
| **1982** | 0 | 0.65 | 0 | 0.21 | 0 | 0 | 4.86 | 0.26 | 0 | 0 | 1.09 | 376.74 | 11.86 | 0 | 0 | 0.13 | 0.97 |
| **1983** | 0 | 1.94 | 0 | 0.23 | 0 | 0 | 16.13 | 0.26 | 0 | 0 | 0 | 7.00 | 18.53 | 0 | 0 | 0.13 | 0 |
| **1984** | 0 | 1.46 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 33.06 | 0 | 0 | 319.63 | 0 | 0 | 0 | 3.82 |
| **1985** | 0.26 | 3.29 | 0 | 0 | 1.80 | 62.47 | 8.49 | 0 | 0 | 0 | 0 | 219.42 | 37.06 | 0 | 0.71 | 0 | 7.78 |
| **1986** | 2.26 | 0.62 | 0 | 0 | 2.48 | 1.20 | 0.69 | 0 | 0 | 1.54 | 1.03 | 4.38 | 197.49 | 1.72 | 0 | 0 | 0 |
| **1987** | 122.92 | 127.36 | 0 | 0 | 1.03 | 22.88 | 0 | 0 | 0 | 0 | 1.72 | 274.02 | 0 | 0.00 | 0 | 0 | 1.46 |
| **1988** | 0.51 | 29.61 | 0.33 | 0 | 0 | 0 | 0.97 | 0 | 0 | 0 | 0 | 36.54 | 1.64 | 4.08 | 0 | 0 | 2.01 |
| **1989** | 0.26 | 56.39 | 0 | 0 | 0 | 0 | 37.73 | 1.95 | 0 | 0 | 0 | 20.78 | 1.54 | 0 | 0 | 0.15 | 0.69 |
| **1990** | 6.43 | 14.52 | 0.19 | 0 | 0 | 0 | 7.48 | 0 | 0 | 0 | 6.48 | 40.37 | 1.30 | 0 | 0 | 0.17 | 0.67 |
| **1991** | | | | | | | | | | | | | | | | | |
| **1992** | 0 | 0.97 | 0.21 | 0 | 0 | 0 | 6.92 | 0 | 0 | 0 | 0.65 | 18.53 | 3.55 | 37.43 | 1.94 | 0.70 | 0.14 |
| **1993** | 0 | 38.63 | 0 | 0 | 14.75 | 0 | 0 | 0 | 0 | 93.96 | 0 | 403.09 | 0 | 199.03 | 0 | 1.39 | 0.12 |
| **1994** | 10.81 | 9.80 | 0 | 0 | 0.65 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6.77 | 0 | 0 | 0.60 | 0.42 |
| **1995** | 0.45 | 8.09 | 0 | 0 | 0 | 0 | 1.69 | 0 | 0 | 0 | 29.23 | 614.67 | 38.25 | 30.11 | 0 | 0.10 | 1.90 |
| **1996** | 0.86 | 0 | 0.22 | 0 | 0 | 0 | 1.37 | 0 | 0 | 0 | 0 | 2.15 | 0.42 | 0 | 0 | 0.34 | 0.64 |
| **1997** | 0.77 | 0.25 | 0 | 0 | 0 | 0 | 0.51 | 0 | 0 | 0 | 0 | 0 | 0 | 0.39 | 0 | 0.56 | 1.23 |
| **1998** | 0 | 0.29 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7.53 | 1.02 | 0 | 0 | 0.61 | 0.09 |
| **1999** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.21 | 0 | 0 | 0 | 3.84 | 3.61 | 1.42 | 0 | 0.03 | 0.28 |
| **2000** | 0 | 0 | 0 | 0 | 0 | 0 | 0.61 | 0 | 0 | 0 | 0 | 0 | 0 | 0.47 | 0 | 0.18 | 0.10 |
| **2001** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6.14 | 0 | 34.73 | 0 | 0 | 83.95 | 0.04 | 0 | 0 | 0.44 |
| **2002** | 0 | 2.39 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.71 | 0 | 0 | 0.03 | 14.85 |
| **Total** | 145.55 | 306.20 | 0.96 | 0.44 | 20.88 | 86.74 | 87.80 | 11.27 | 0 | 169.12 | 53.56 | 2123.01 | 745.97 | 275.38 | 3.38 | 5.70 | 39.64 |
| **Mean** | 4.55 | 9.57 | 0.03 | 0.01 | 0.65 | 2.71 | 2.74 | 0.35 | 0 | 5.29 | 1.67 | 66.34 | 23.31 | 8.61 | 0.11 | 0.18 | 1.24 |
| **CV** | 477.34 | 260.70 | 276.69 | 394.15 | 403.38 | 429.01 | 265.86 | 325.67 | 0 | 344.40 | 326.29 | 222.13 | 282.48 | 415.17 | 347.75 | 175.76 | 234.66 |

Table 2 (cont.) Mean weight of pollock catch from each stratum of 4VWXmn* caught during RV summer surveys.

| | 457 | 458 | 459 | 460 | 461 | 462 | 463 | 464 | 465 | 466 | 470 | 471 | 472 | 473 | 475 | 477 | 478 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1970** | 0 | 0 | 3.80 | 53.88 | 0 | 0 | 0 | 0 | 0.78 | 0 | 3.28 | 0 | 5.15 | 0 | 0 | 0 | 7.29 |
| **1971** | 0 | 0 | 0.44 | 0 | 0 | 1.30 | 0 | 0 | 11.28 | 0 | 10.88 | 0 | 14.00 | 0 | 0 | 0 | 4.38 |
| **1972** | 0 | 0 | 0 | 5.00 | 0 | 0 | 0 | 0.19 | 0 | 0 | 0.76 | 0 | 1.58 | 0 | 0 | 0 | 3.50 |
| **1973** | 0 | 0 | 0.29 | 10.29 | 1.03 | 0 | 0 | 0.22 | 0 | 0 | 61.48 | 1.09 | 3.83 | 0 | 0 | 6.45 | 6.32 |
| **1974** | 0 | 0 | 0 | 0 | 0 | 34.51 | 0 | 0 | 32.90 | 0 | 8.24 | 0 | 3.09 | 0 | 0 | 0 | 0 |
| **1975** | 0 | 0 | 0 | 12.89 | 70.00 | 11.48 | 8.53 | 0 | 2.04 | 0 | 0.97 | 0 | 0 | 0 | 0 | 0 | 3.28 |
| **1976** | 0 | 0 | 0.40 | 0.00 | 0 | 2.06 | 13.13 | 0.32 | 7.19 | 0 | 436.70 | 0 | 8.81 | 0 | 0 | 0 | 0 |
| **1977** | 0 | 0 | 0.63 | 4.86 | 12.33 | 0 | 4.08 | 4.52 | 8.39 | 0 | 57.46 | 20.65 | 5.69 | 1.09 | 0.65 | 0 | 2.47 |
| **1978** | 3.28 | 0 | 0.24 | 52.10 | 0 | 19.11 | 0 | 4.62 | 1.03 | 0 | 247.29 | 13.32 | 0.46 | 0 | 0 | 0 | 3.50 |
| **1979** | 0 | 0 | 0 | 9.38 | 0 | 2.43 | 12.08 | 2.53 | 1.65 | 0 | 15.31 | 0 | 1.03 | 0 | 0 | 1.75 | 10.98 |
| **1980** | 0 | 0 | 0 | 330.11 | 0 | 148.41 | 2.06 | 0.40 | 0 | 0 | 2.73 | 22.36 | 43.67 | 1.52 | 0 | 0 | 0 |
| **1981** | 0 | 0 | 0 | 2.92 | 0 | 37.91 | 15.01 | 0 | 3.70 | 0 | 83.85 | 5.66 | 17.01 | 0 | 0 | 0 | 0 |
| **1982** | 0.49 | 0 | 0 | 37.29 | 18.88 | 2.20 | 1.23 | 0 | 0.31 | 0 | 0 | 0 | 1.46 | 0 | 0 | 0 | 0 |
| **1983** | 0 | 1.30 | 1.31 | 55.42 | 10.21 | 0 | 6.32 | 46.22 | 2.08 | 0 | 134.90 | 3.40 | 12.58 | 0 | 0 | 7.21 | 0 |
| **1984** | 0 | 0 | 59.99 | 195.99 | 11.87 | 5.92 | 0 | 0.21 | 3.89 | 0 | 39.92 | 10.68 | 9.33 | 0 | 3.60 | 0 | 0 |
| **1985** | 0 | 0 | 5.99 | 38.89 | 24.45 | 69.56 | 4.38 | 8.00 | 8.17 | 12.31 | 145.20 | 90.59 | 510.42 | 1.46 | 0 | 0 | 14.91 |
| **1986** | 0 | 0.21 | 27.45 | 27.25 | 13.04 | 38.04 | 8.75 | 0.97 | 0.78 | 1.56 | 66.40 | 16.47 | 19.04 | 5.35 | 2.57 | 0 | 1.09 |
| **1987** | 0 | 0.00 | 16.41 | 605.03 | 43.43 | 17.07 | 22.13 | 2.93 | 22.97 | 1.09 | 59.71 | 303.61 | 7.98 | 1.54 | 0.00 | 58.20 | 0 |
| **1988** | 0 | 0.34 | 25.41 | 31.20 | 11.48 | 14.93 | 1.09 | 2.95 | 3.90 | 0 | 190.86 | 26.64 | 27.81 | 0 | 0 | 0 | 17.50 |
| **1989** | 0 | 0 | 0.78 | 107.96 | 7.11 | 5.58 | 28.82 | 31.84 | 9.41 | 6.56 | 21.14 | 3.60 | 70.51 | 0 | 6.69 | 0 | 0 |
| **1990** | 0 | 0 | 0 | 198.15 | 1.03 | 18.74 | 15.19 | 1.60 | 1.80 | 0 | 385.00 | 11.52 | 3.60 | 0 | 0 | 1.53 | 70.00 |
| **1991** | | | | 41.81 | 11.05 | 0 | 6.15 | | 23.13 | 0 | 105.90 | 17.74 | 3.22 | 0 | 0 | 2.06 | 0 |
| **1992** | 0 | 0 | 8.75 | 7.97 | 1.94 | 7.53 | 9.12 | 13.61 | 9.55 | 27.71 | 110.83 | 9.24 | 38.89 | 0.49 | 0 | 3.45 | 57.88 |
| **1993** | 0.49 | 0 | 0.25 | 27.98 | 4.63 | 14.40 | 8.34 | 3.34 | 2.54 | 252.29 | 7.29 | 197.73 | 15.53 | 0.97 | 0.49 | 29.87 | 104.03 |
| **1994** | 0 | 4.85 | 0 | 19.32 | 1.03 | 4.17 | 1.51 | 3.16 | 17.27 | 0 | 9.96 | 3.50 | 7.99 | 15.65 | 0.49 | 4.56 | 35.00 |
| **1995** | 0 | 0.05 | 0.08 | 2.79 | 3.15 | 0.71 | 4.77 | 7.16 | 18.16 | 0 | 1.28 | 5.12 | 67.59 | 5.21 | 0.69 | 1.97 | 112.23 |
| **1996** | 0 | 0 | 1.10 | 17.12 | 1.72 | 0.50 | 3.12 | 3.21 | 41.49 | 60.44 | 15.07 | 1.65 | 3.27 | 15.99 | 4.37 | 2.32 | 121.87 |
| **1997** | 0 | 0 | 1.19 | 2.57 | 24.73 | 8.25 | 16.14 | 4.93 | 5.57 | 0 | 14.77 | 1.47 | 96.42 | 2.87 | 15.56 | 11.19 | 8.95 |
| **1998** | 0 | 0 | 0 | 1.26 | 20.46 | 0.58 | 3.98 | 2.03 | 8.62 | 0 | 0 | 1.66 | 5.86 | 4.69 | 3.42 | 3.72 | 0 |
| **1999** | 0 | 0 | 0.28 | 8.99 | 0.41 | 2.12 | 0 | 4.85 | 2.98 | 55.36 | 4.50 | 95.60 | 4.59 | 2.54 | 1.21 | 3.46 | 66.05 |
| **2000** | 0 | 0.95 | 0.73 | 16.60 | 1.14 | 0 | 0.92 | 2.88 | 0.52 | 188.69 | 3.47 | 3.42 | 8.92 | 0 | 1.38 | 2.28 | 7.44 |
| **2001** | 0 | 0 | 0.48 | 0.63 | 0.20 | 0.49 | 3.51 | 4.47 | 2.70 | 5.57 | 22.74 | 1.70 | 30.58 | 0 | 2.30 | 6.72 | 22.07 |
| **2002** | 0.10 | 0.54 | 0 | 4.79 | 2.14 | 1.27 | 17.76 | 0.27 | 2.10 | 0 | 3.06 | 1.27 | 29.25 | 0.73 | 0.95 | 16.59 | 178.30 |
| **Total** | 4.36 | 8.24 | 156.00 | 1930.42 | 297.48 | 469.25 | 218.12 | 157.44 | 256.90 | 611.59 | 2270.95 | 869.69 | 1079.17 | 60.10 | 44.36 | 163.33 | 859.03 |
| **Mean** | 0.14 | 0.26 | 4.87 | 58.50 | 9.01 | 14.22 | 6.61 | 4.92 | 7.78 | 18.53 | 68.82 | 26.35 | 32.70 | 1.82 | 1.34 | 4.95 | 26.03 |
| **CV** | 430.38 | 344.77 | 250.98 | 206.91 | 164.16 | 200.72 | 110.77 | 195.15 | 128.13 | 294.98 | 155.99 | 240.50 | 271.28 | 215.55 | 223.34 | 228.51 | 170.40 |

*Edge strata (496-498) were surveyed from 1995 to the present and include many zero catches. Mean weights of pollock from edge strata are not shown here.

Table 3. Stratified mean catch per tow of pollock in two size classes. Probability values ($p$) from randomization test of association between pollock catch and water temperature (Perry and Smith 1994).

| | | Pollock ≤ 40 cm | | Pollock > 40cm | |
|---|---|---|---|---|---|
| Year | Area | mean | $p$-value | mean | $p$-value |
| 1970 | 4VW | 2.62 | 0.256 | 0.74 | 0.265 |
| | 4X | 0.46 | 0.702 | 2.59 | 0.189 |
| 1971 | 4VW | 0.91 | 0.080 | 0.39 | 0.093 |
| | 4X | 1.30 | 0.142 | 0.92 | 0.868 |
| 1972 | 4VW | 0.02 | 0.676 | 0.04 | 0.408 |
| | 4X | 0.54 | 0.681 | 5.49 | 0.956 |
| 1973 | 4VW | 0.14 | 0.489 | 0.14 | 0.056 |
| | 4X | 1.04 | 0.447 | 5.40 | 0.198 |
| 1974 | 4VW | 0.12 | 0.448 | 2.12 | 0.180 |
| | 4X | 0.13 | 0.238 | 1.70 | 0.021 |
| 1975 | 4VW | 0.00 | NA | 1.29 | 0.003 |
| | 4X | 0.02 | 0.494 | 0.88 | 0.406 |
| 1976 | 4VW | 0.03 | 0.282 | 0.27 | 0.059 |
| | 4X | 0.08 | 0.162 | 8.40 | 0.779 |
| 1977 | 4VW | 0.06 | 0.892 | 0.42 | 0.001 |
| | 4X | 1.12 | 0.576 | 16.58 | 0.243 |
| 1978 | 4VW | 0.16 | 0.808 | 1.04 | 0.007 |
| | 4X | 0.05 | 0.464 | 4.92 | 0.243 |
| 1979 | 4VW | 0.00 | NA | 0.54 | 0.017 |
| | 4X | 0.05 | 0.076 | 6.00 | 0.626 |
| 1980 | 4VW | 1.17 | 0.050 | 10.15 | 0.064 |
| | 4X | 0.03 | 0.003 | 4.85 | 0.968 |
| 1981 | 4VW | 0.18 | 0.763 | 0.70 | 0.556 |
| | 4X | 0.13 | 0.211 | 4.47 | 0.126 |
| 1982 | 4VW | 2.61 | 0.402 | 0.73 | 0.003 |
| | 4X | 1.36 | 0.634 | 4.89 | 0.785 |
| 1983 | 4VW | 0.60 | 0.188 | 2.96 | 0.123 |
| | 4X | 0.35 | 0.330 | 3.73 | 0.079 |
| 1984 | 4VW | 0.18 | 0.011 | 4.73 | 0.195 |
| | 4X | 1.15 | 0.400 | 6.21 | 0.004 |
| 1985 | 4VW | 2.93 | 0.403 | 3.87 | 0.062 |
| | 4X | 5.28 | 0.473 | 31.00 | 0.442 |
| 1986 | 4VW | 0.26 | 0.528 | 3.18 | 0.032 |
| | 4X | 1.55 | 0.708 | 9.06 | 0.965 |
| 1987 | 4VW | 2.46 | 0.282 | 17.13 | 0.366 |
| | 4X | 3.03 | 0.570 | 13.76 | 0.234 |
| 1988 | 4VW | 0.29 | 0.157 | 2.51 | 0.900 |
| | 4X | 0.43 | 0.979 | 20.77 | 0.874 |
| 1989 | 4VW | 0.25 | 0.350 | 3.97 | 0.079 |
| | 4X | 0.12 | 0.320 | 6.55 | 0.542 |
| 1990 | 4VW | 1.42 | 0.009 | 5.39 | 0.012 |
| | 4X | 37.79 | 0.761 | 29.00 | 0.765 |
| 1991 | 4VW | 1.76 | 0.002 | 2.89 | 0.001 |
| | 4X | 1.74 | 0.779 | 10.16 | 0.453 |
| 1992 | 4VW | 1.12 | 0.025 | 1.91 | 0.001 |
| | 4X | 1.69 | 0.454 | 7.85 | 0.058 |
| 1993 | 4VW | 1.78 | 0.003 | 7.84 | 0.017 |
| | 4X | 14.94 | 0.876 | 23.67 | 0.036 |
| 1994 | 4VW | 1.98 | 0.056 | 1.65 | 0.004 |
| | 4X | 0.39 | 0.179 | 6.38 | 0.711 |
| 1995 | 4VW | 3.89 | 0.004 | 2.59 | 0.004 |
| | 4X | 2.45 | 0.600 | 7.31 | 0.298 |
| 1996 | 4VW | 1.33 | 0.105 | 2.94 | 0.038 |
| | 4X | 0.95 | 0.823 | 22.90 | 0.220 |
| 1997 | 4VW | 1.06 | 0.005 | 1.69 | 0.002 |
| | 4X | 2.33 | 0.591 | 7.32 | 0.410 |
| 1998 | 4VW | 0.29 | 0.015 | 1.15 | 0.003 |
| | 4X | 0.45 | 0.002 | 1.83 | 0.252 |
| 1999 | 4VW | 0.27 | 0.069 | 1.02 | 0.001 |
| | 4X | 0.95 | 0.097 | 6.06 | 0.666 |
| 2000 | 4VW | 0.56 | 0.316 | 1.58 | 0.048 |
| | 4X | 4.03 | 0.541 | 2.00 | 0.417 |
| 2001 | 4VW | 5.71 | 0.992 | 0.70 | 0.228 |
| | 4X | 7.06 | 0.049 | 6.49 | 0.036 |
| 2002 | 4VW | 2.70 | 0.259 | 0.26 | 0.001 |
| | 4X | 4.18 | 0.019 | 4.48 | 0.084 |

Table 4. Factors describing the concentration of pollock catch in the ITQ survey within NAFO area 4Xopqrs.

| | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|
| Total Catch (kg) | 5766 | 5539 | 1272 | 2017 | 3484 | 6130 | 1252 |
| # sets >75% | 4 | 4 | 14 | 6 | 5 | 5 | 12 |
| %sets >75% | 3% | 3% | 11% | 5% | 4% | 4% | 12% |
| # non-zero sets | 79 | 61 | 74 | 81 | 66 | 53 | 72 |
| %non-zero sets | 61% | 47% | 57% | 63% | 50% | 40% | 55% |

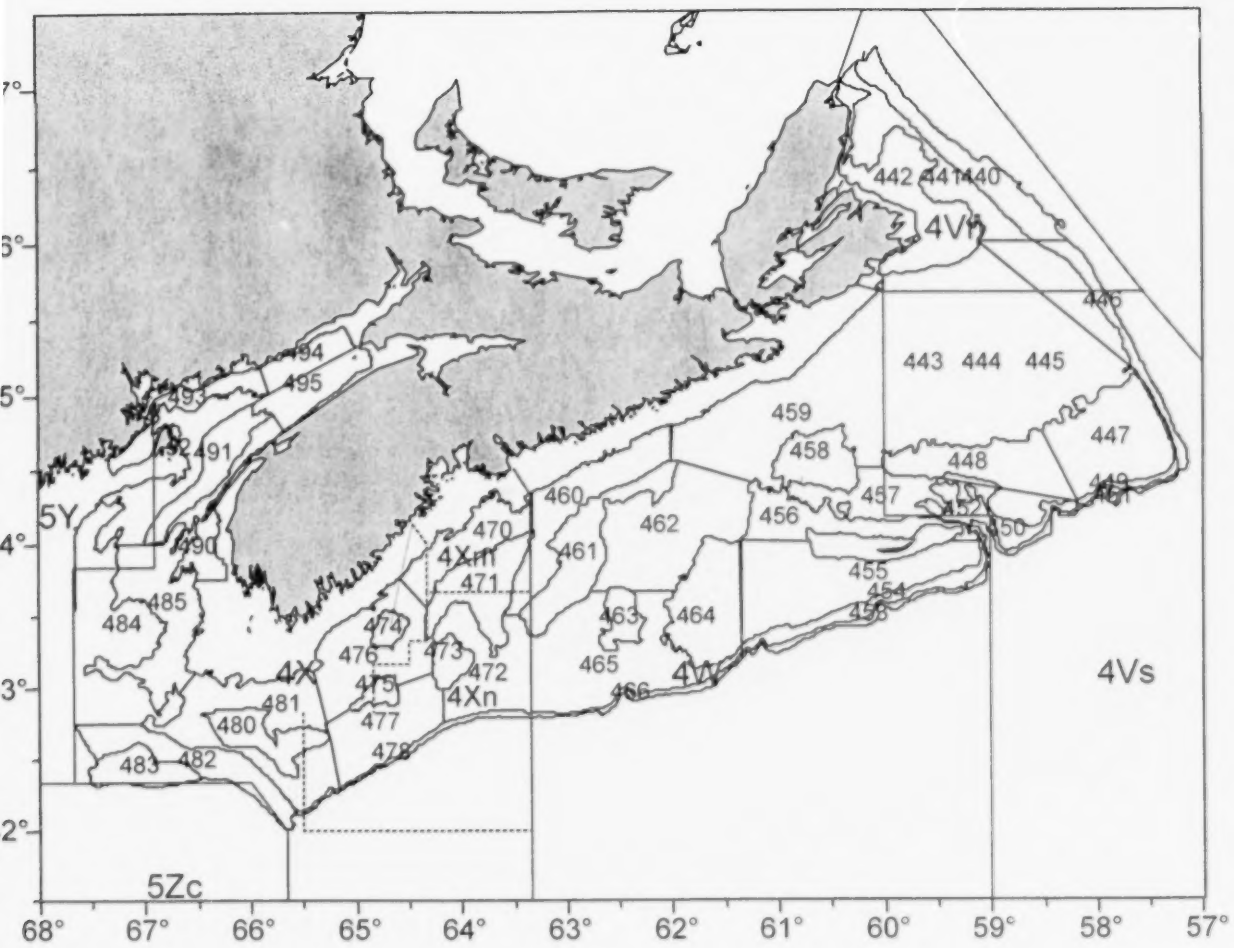



Fig. 1. Scotian Shelf and Bay of Fundy NAFO areas and sampling strata for summer research vessel groundfish surveys. RV strata 470, 471, 472, 473, 475, 477 and 478 roughly correspond with NAFO areas 4Xm and 4Xn and were combined with 4VW data for much of the analyses.

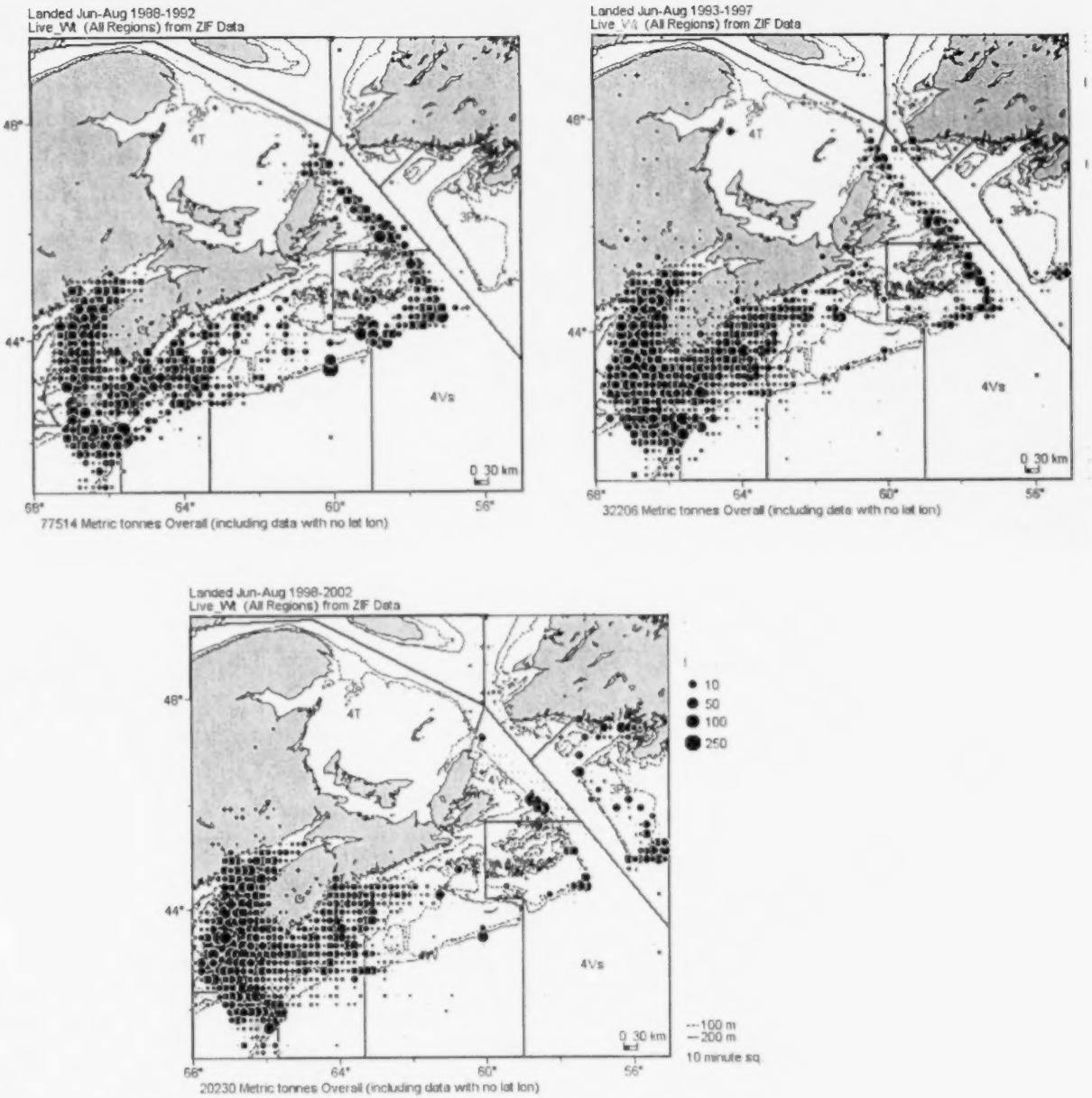



Fig. 2. Pollock landings from the commercial fishery for the months June-August. Data were summarised into 5-year blocks (1988-1992, 1993-1997, and 1998-2002).

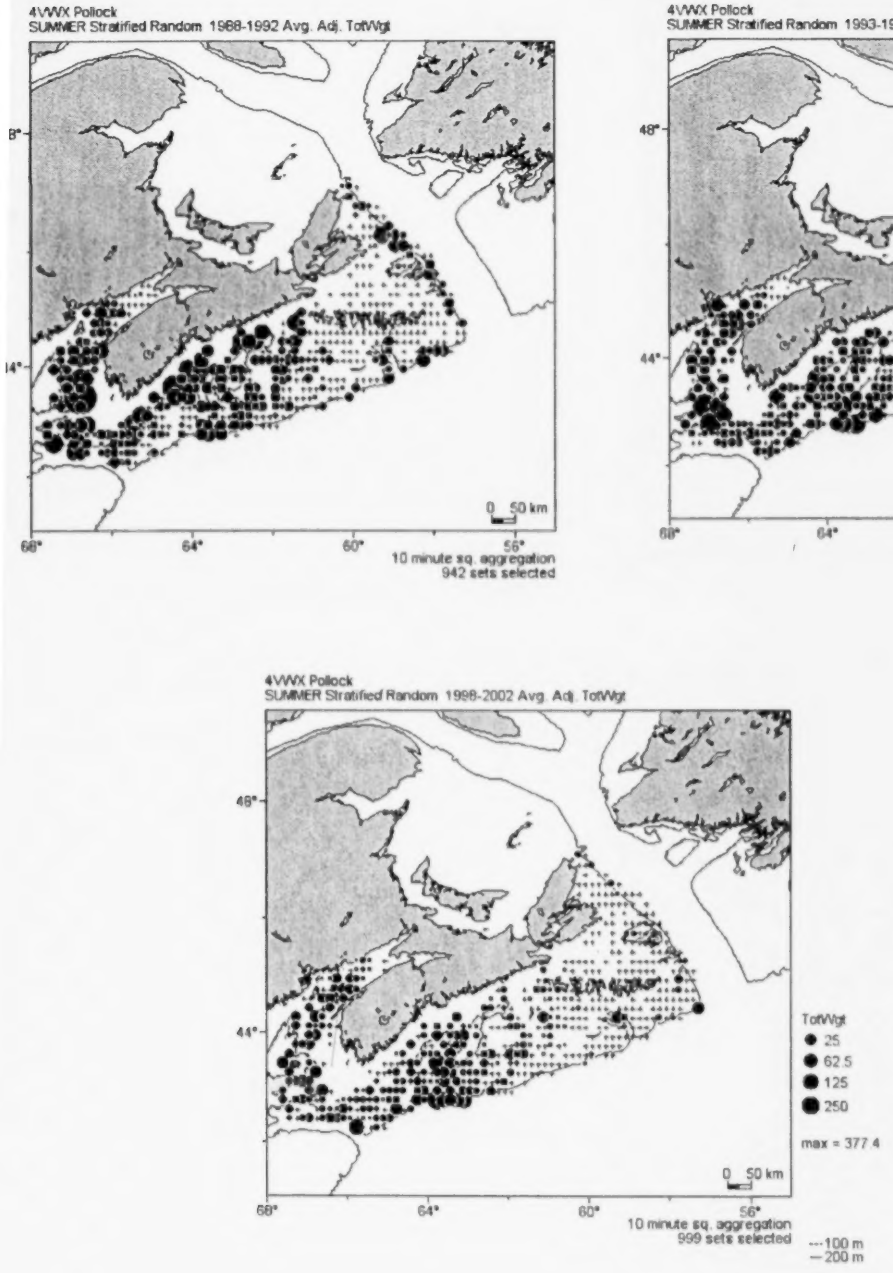
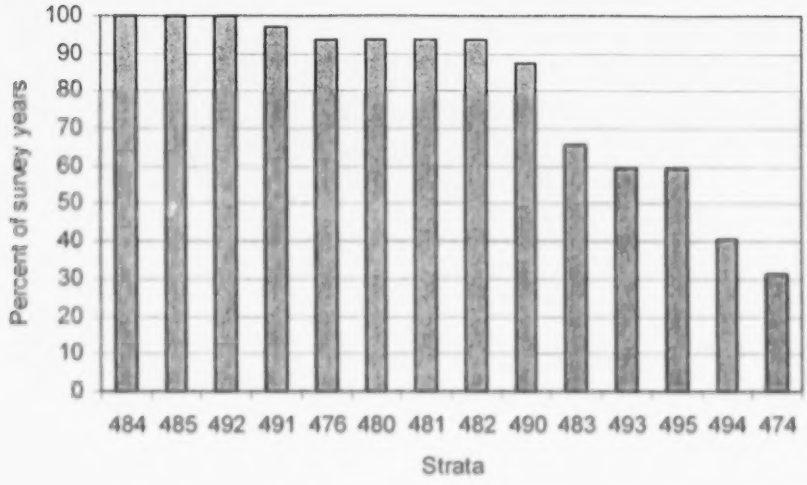



Fig. 3. Pollock weight caught in RV summer groundfish surveys. Data were summarised into 5-year blocks (1988-1992, 1993-1997, and 1998-2002).



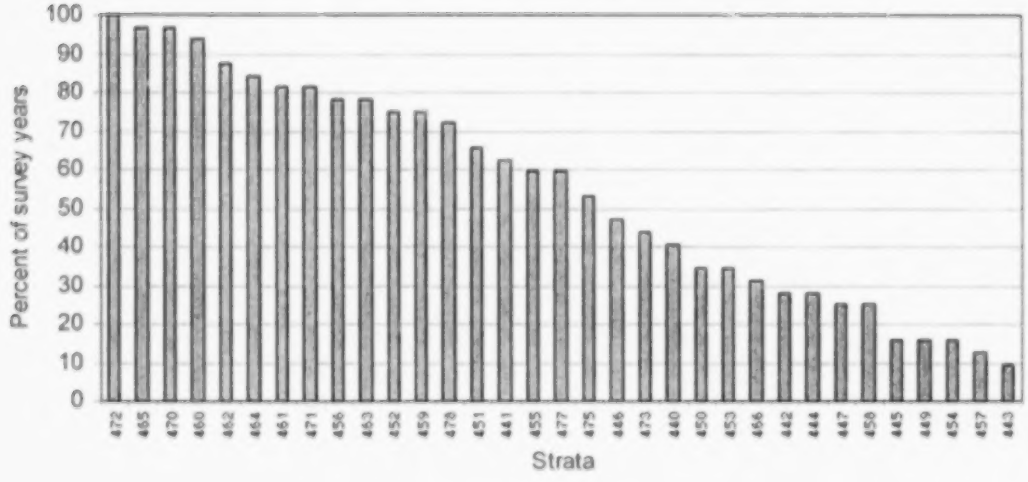




Fig. 4. Percent of years when pollock were present in a given stratum in 4Xoprqs (top panel) and in 4XmnVW (bottom panel) of the annual RV summer groundfish survey.

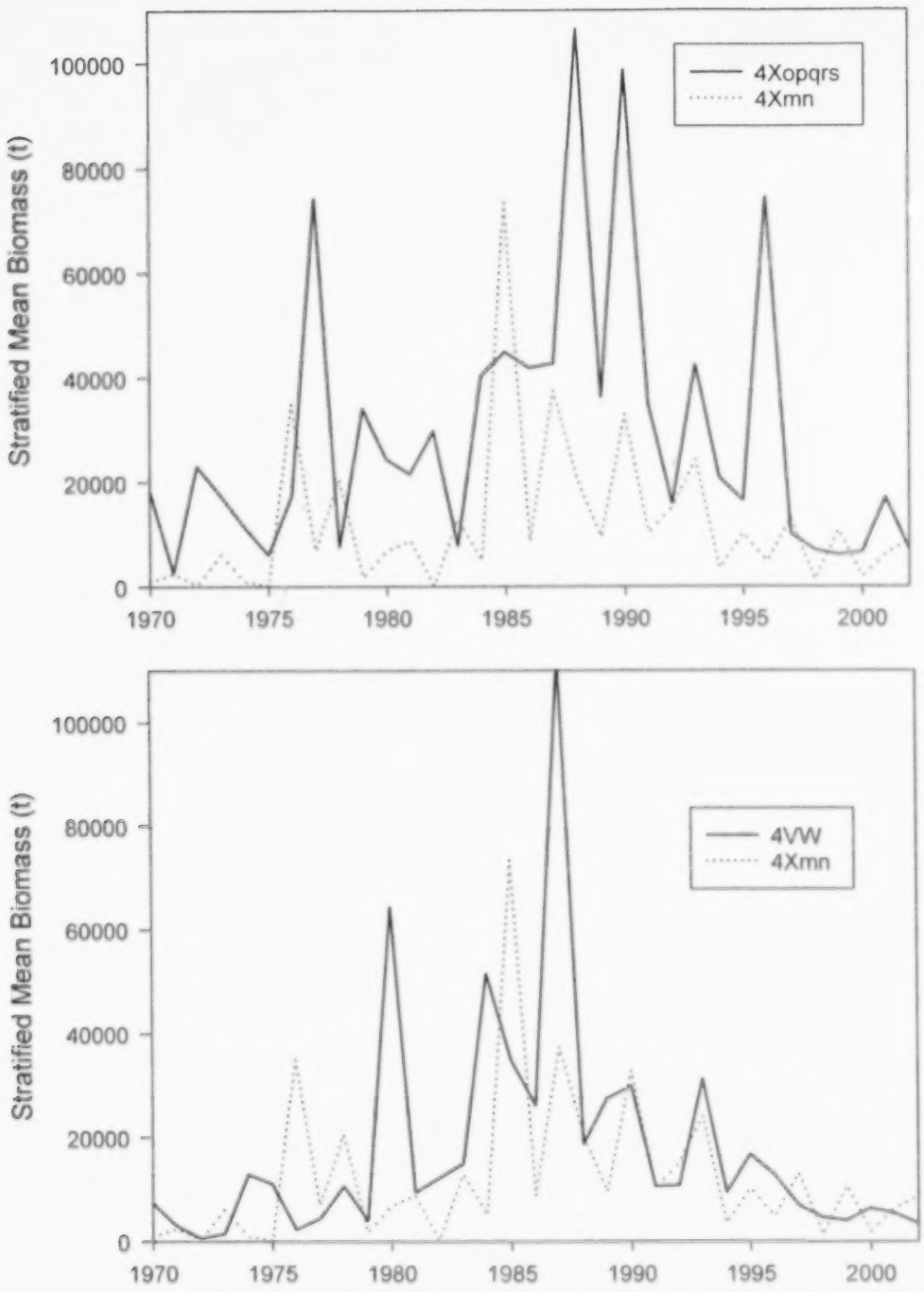



Fig. 5. Stratified mean biomass of pollock caught in RV summer groundfish surveys and extrapolated to area surveyed corresponding to NAFO areas 4Xopqrs (474, 476, 480-485, 490-495, top panel), and 4VW (440-466, 496-498, bottom panel). Total weight for strata in 4Xmn was presented in comparison to both regions.

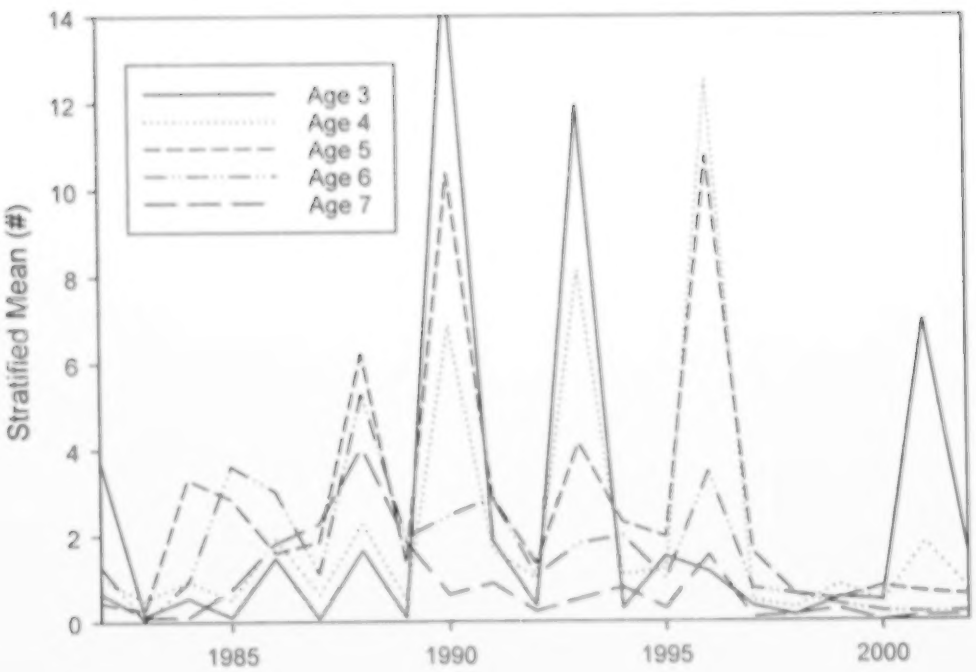



Fig. 6. Age-specific stratified mean pollock catch from RV summer groundfish surveys (1982-2002, 4Xopqrs).

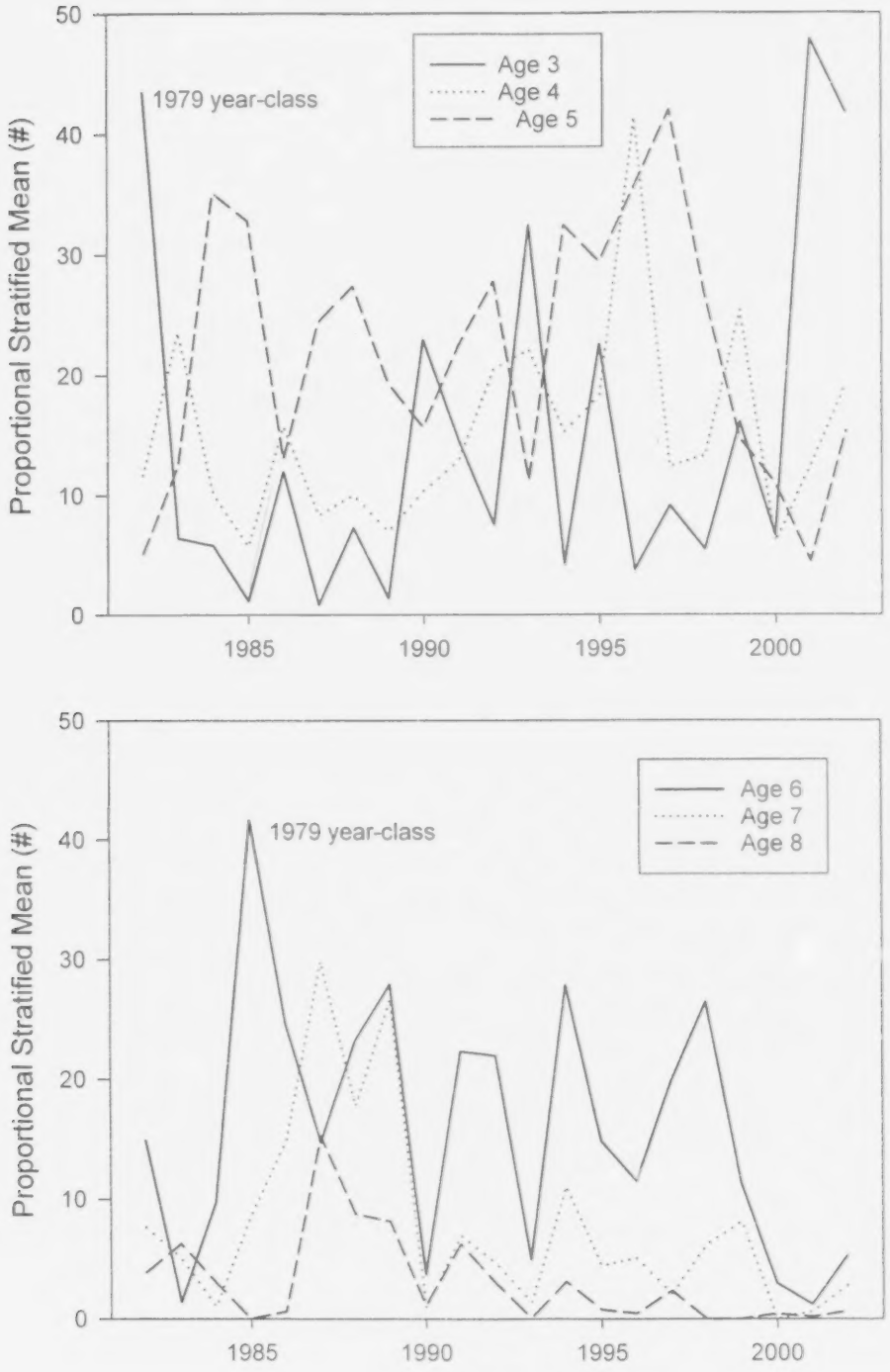



Fig. 7. Age-specific stratified mean catch is presented as a percentage of total annual pollock catch from RV summer groundfish surveys (1982-2002, 4Xopqrs).

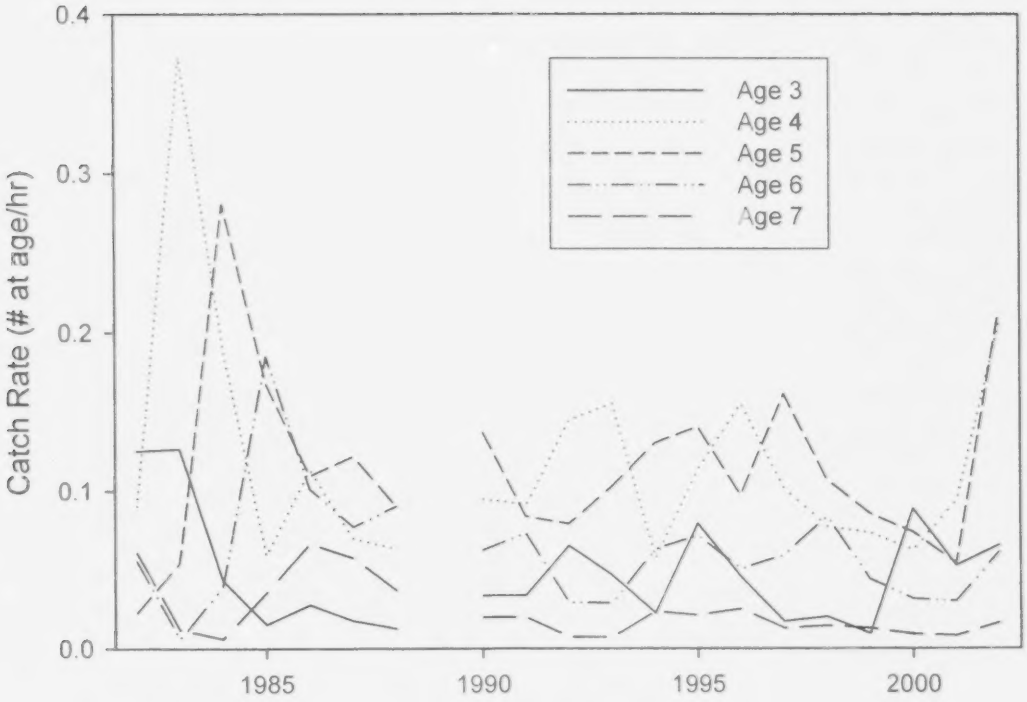



Fig. 8. Catch rate for pollock ages 3-8 landed by tonnage classes 2-3 in 4X5. Catch data from the 1989 fishing season was excluded because of the combined cod, haddock and pollock quota that year.

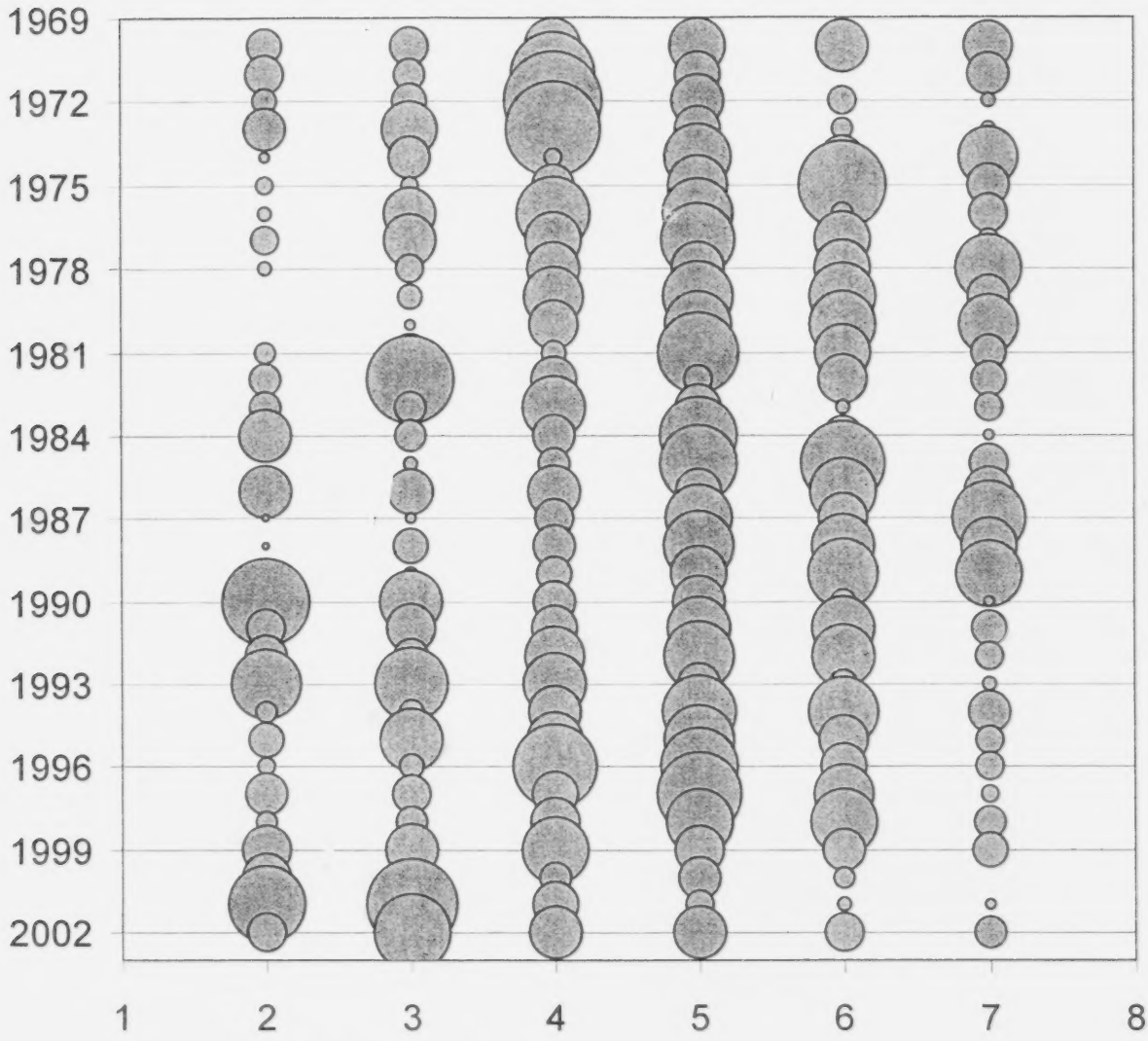



Fig. 9. Catch at age of pollock from RV summer groundfish surveys (1970-2002) from the western Scotian Shelf and Bay of Fundy (4Xopqrs, RV strata: 474, 476, 480-495). Symbol size represents stratified mean catch at age and is proportional to the total catch for the year.

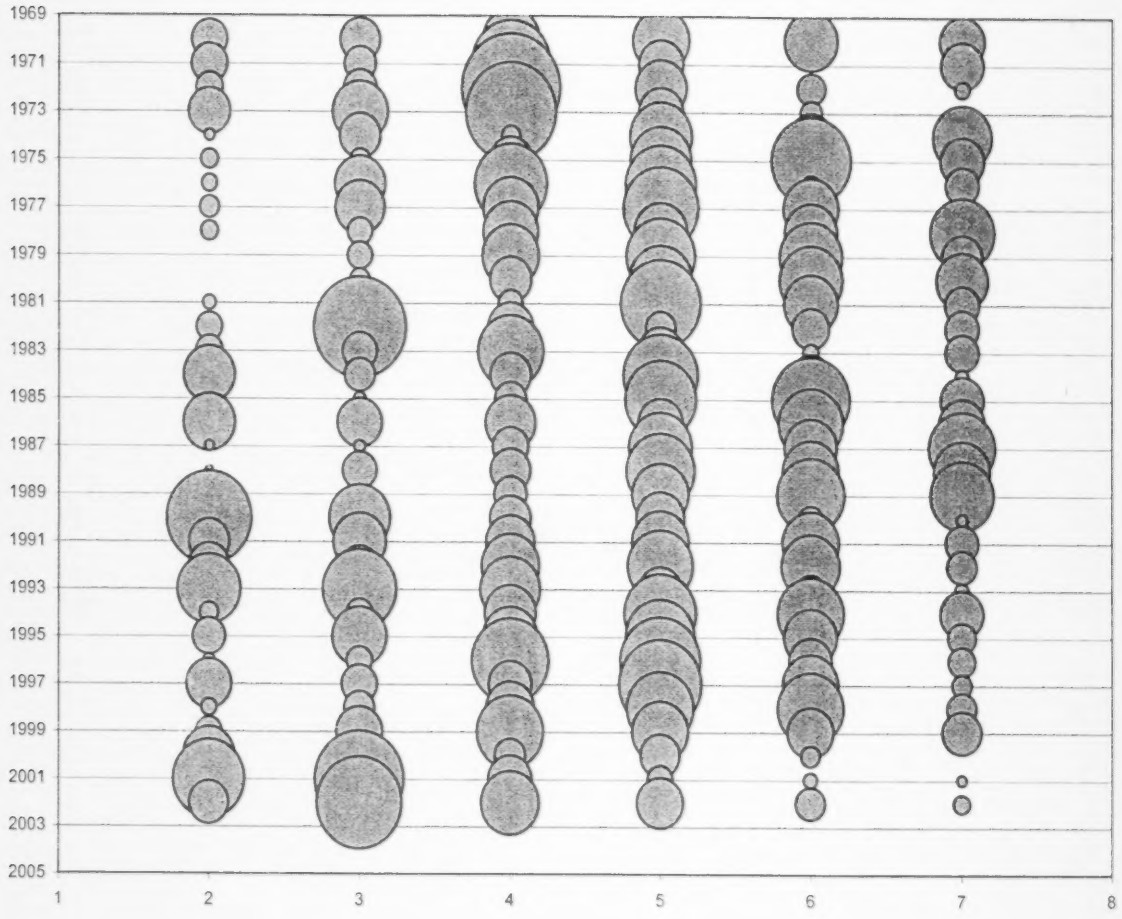



Fig. 10. Catch at age of pollock from RV summer groundfish surveys (1970-2002) for key pollock strata (476, 481-2, 484-5 and 490-1). Symbol size represents stratified mean catch at age and is proportional to the total catch for the year.

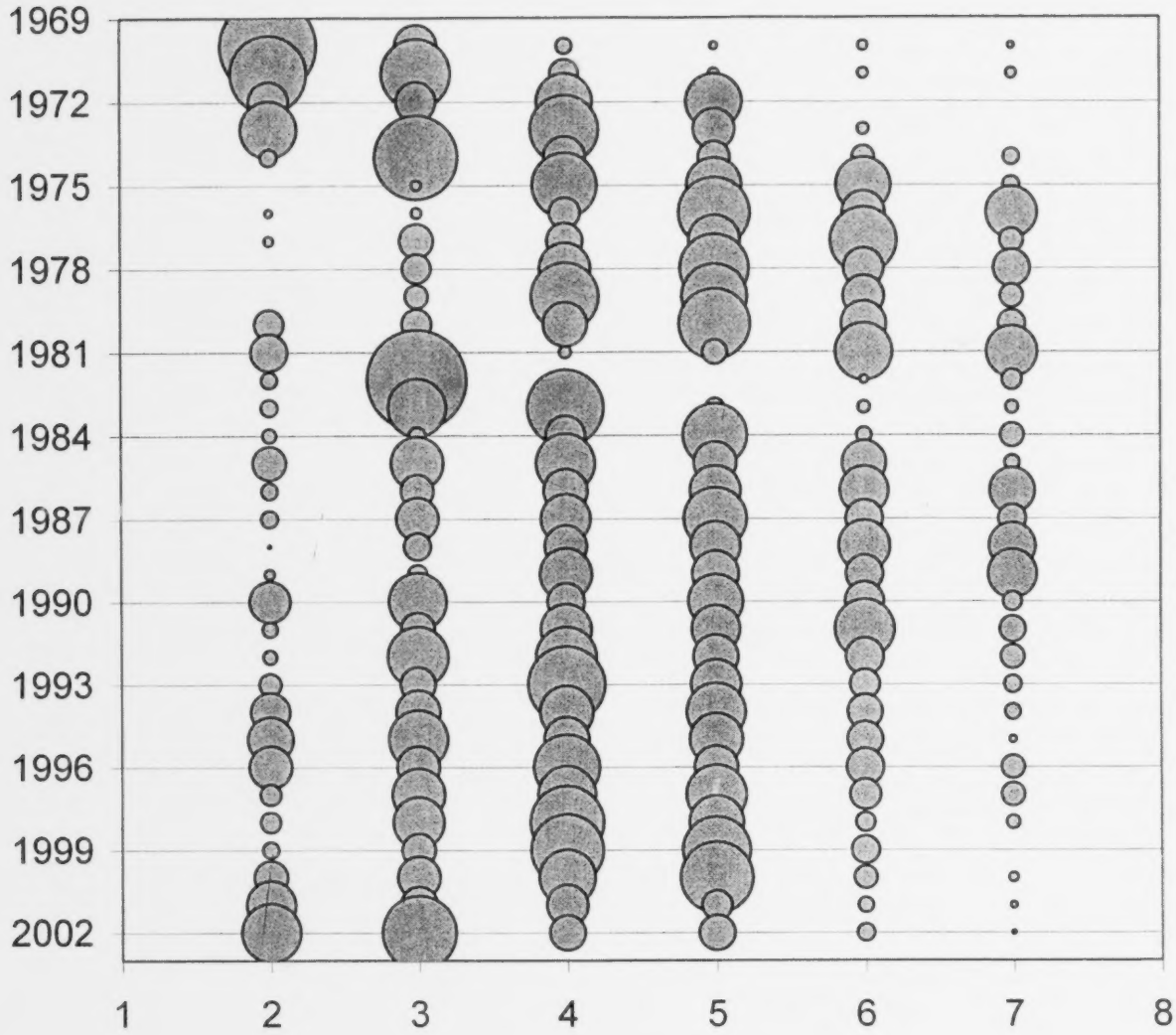



Fig. 11. Catch at age of pollock from RV summer groundfish surveys (1970-2002) from the eastern and central Scotian Shelf (4VWXmn, RV strata: 440-466, 470-473, 475, 477,478, 496-498). Symbol size represents stratified mean catch at age and is proportional to the total catch for the year.

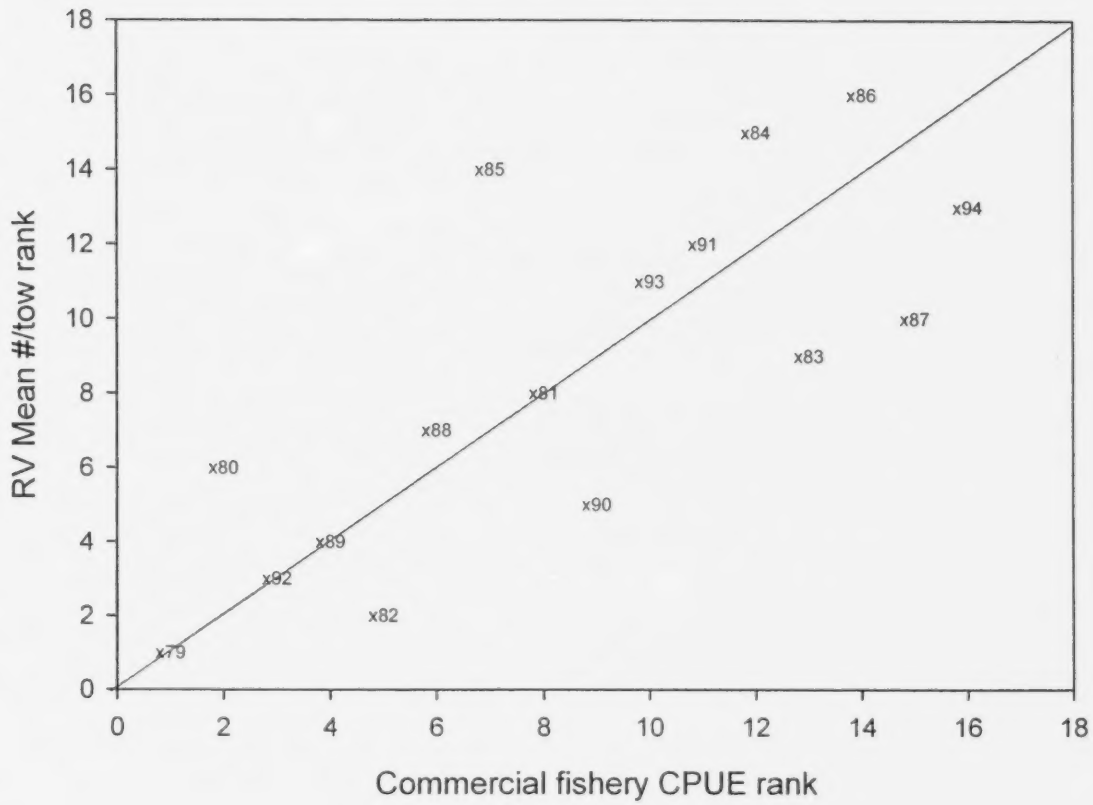



Fig. 12. Relative year-class (1979-1994) strength in the RV summer groundfish survey (4Xopqrs), ranking based on mean number of pollock at age per tow, was linearly related to the ranking of age disaggregated CPUE from commercial fishery. RV data are proportional to the total annual catch to remove year effects.

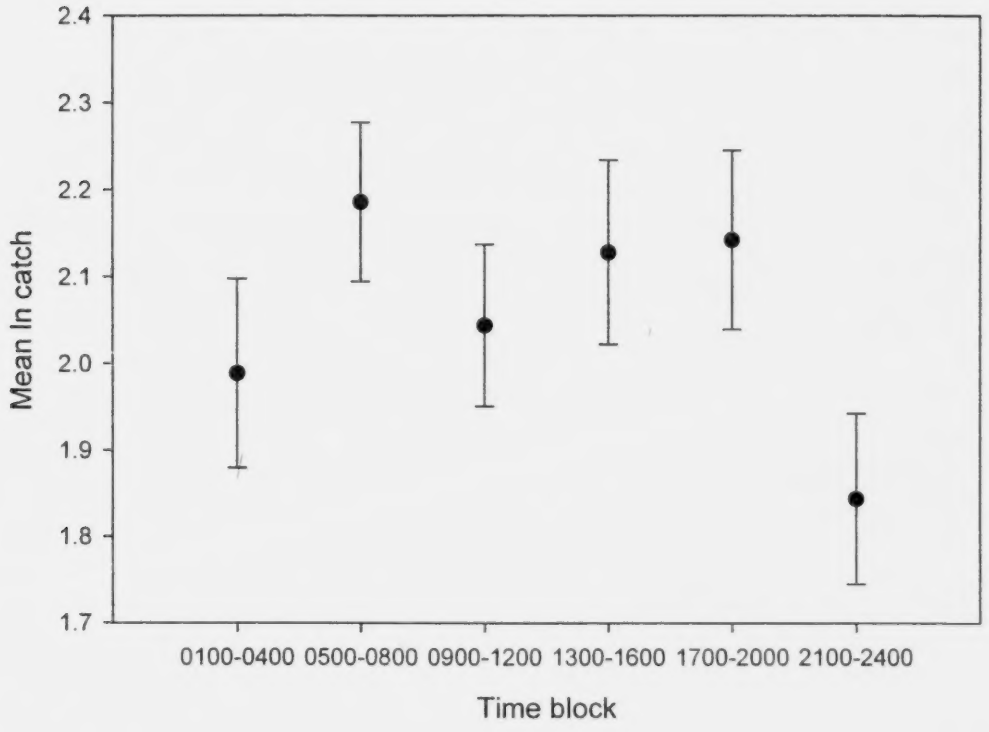



Fig. 13. Mean catch per tow of pollock (plus/minus one standard error) in RV summer groundfish surveys for each of six time blocks, 1970-2002.

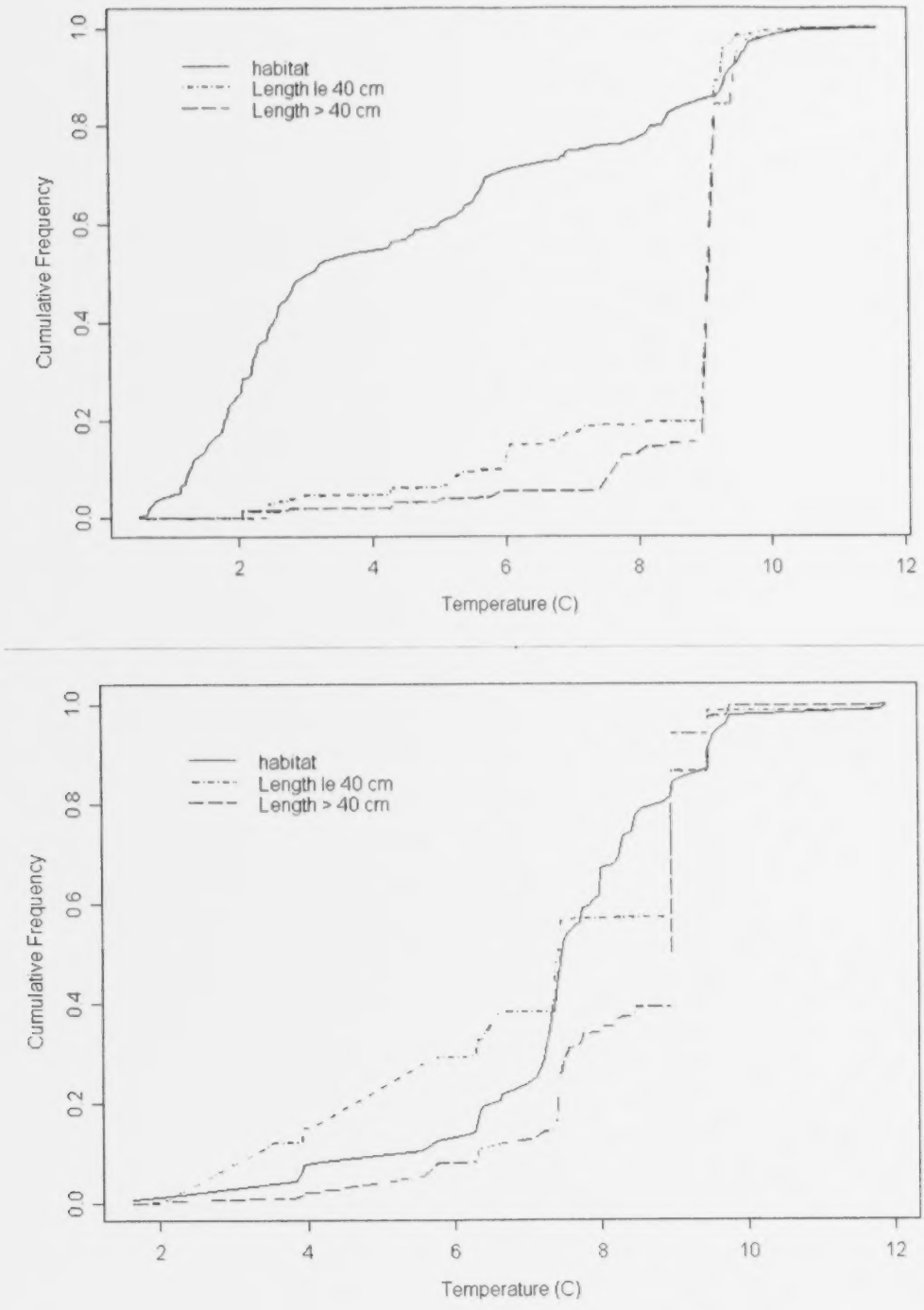



Fig. 14. Cumulative frequency of the catch of pollock in two length classes shown in comparison to the distributions of temperature observed during the RV summer groundfish surveys.

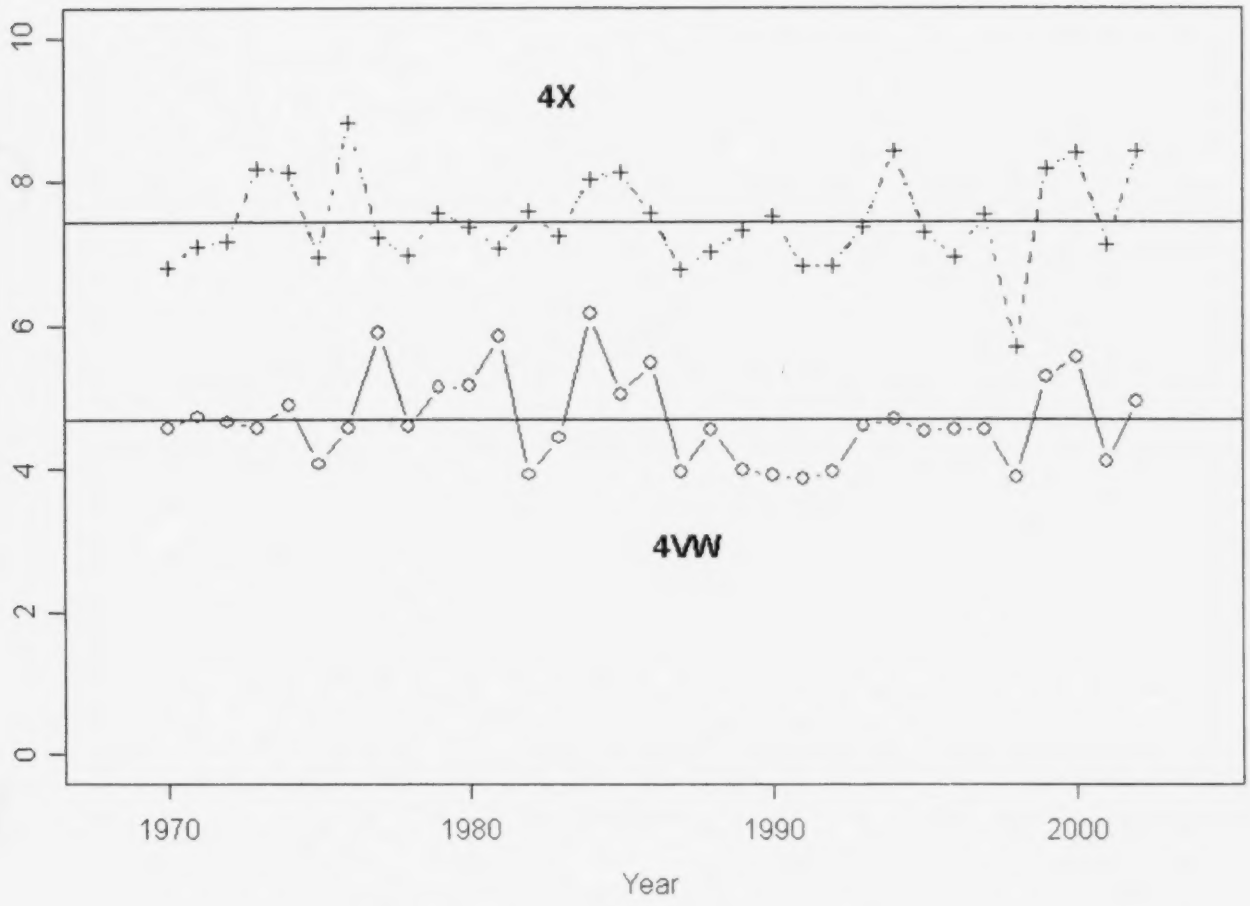



Fig. 15. Time series of bottom temperature observed during summer RV summer groundfish surveys in NAFO Div. 4X and 4W. Means for the two series are shown by horizontal lines.

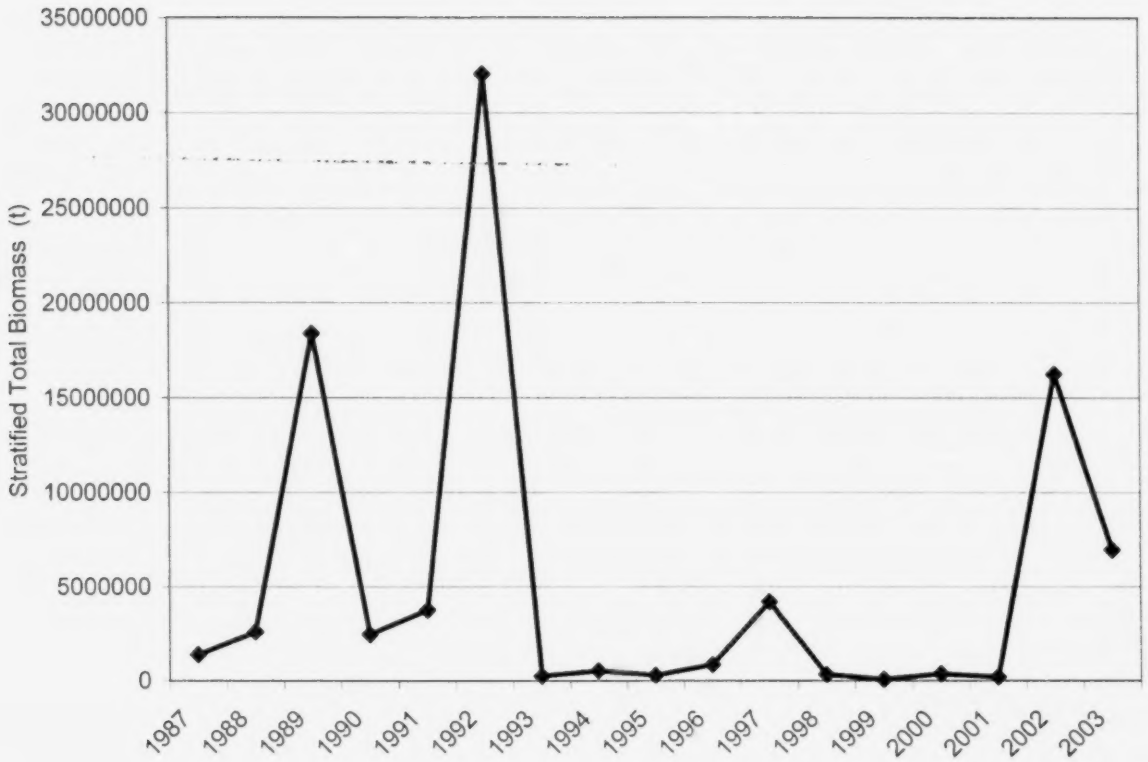



Fig. 16. Annual estimates of pollock biomass in 5Zc (Strata 1,2) in DFO RV Georges Bank surveys, 1986-2003.

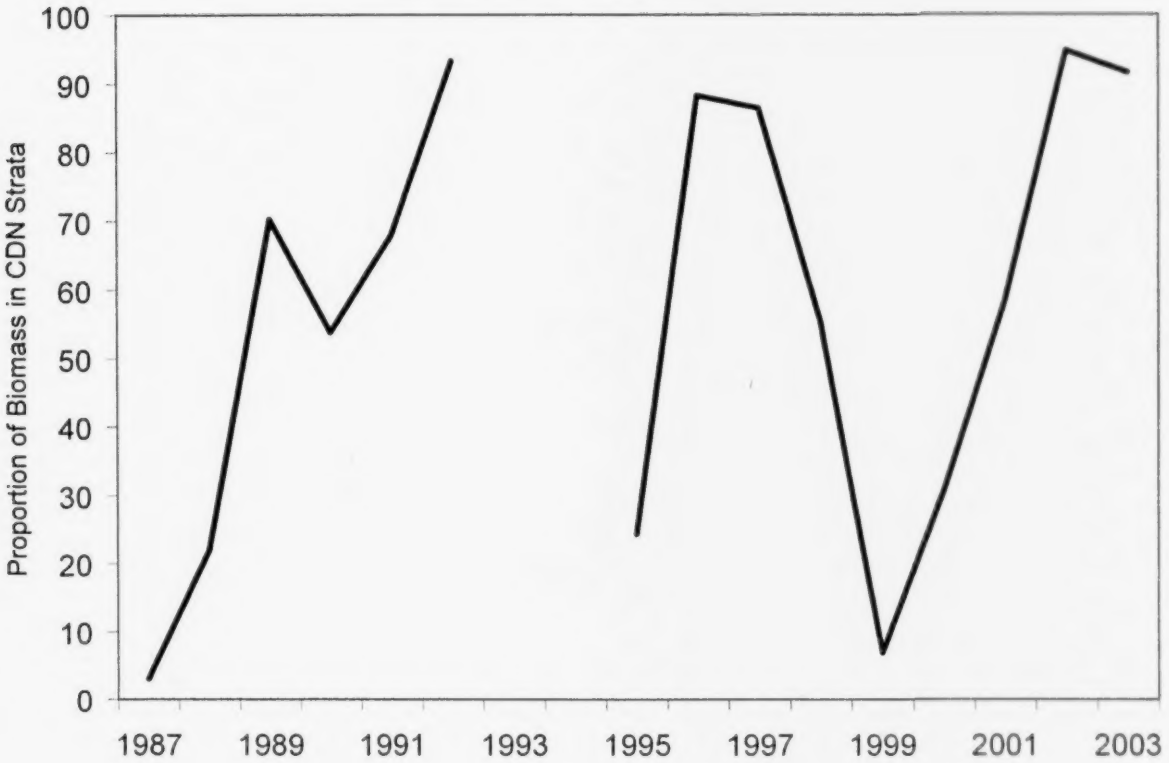



Fig. 17. Proportion of total biomass caught from the Canadian portion of Georges Bank as compared to that caught in US strata. Data were collected during the annual DFO RV Georges Bank survey, 1986-2003.

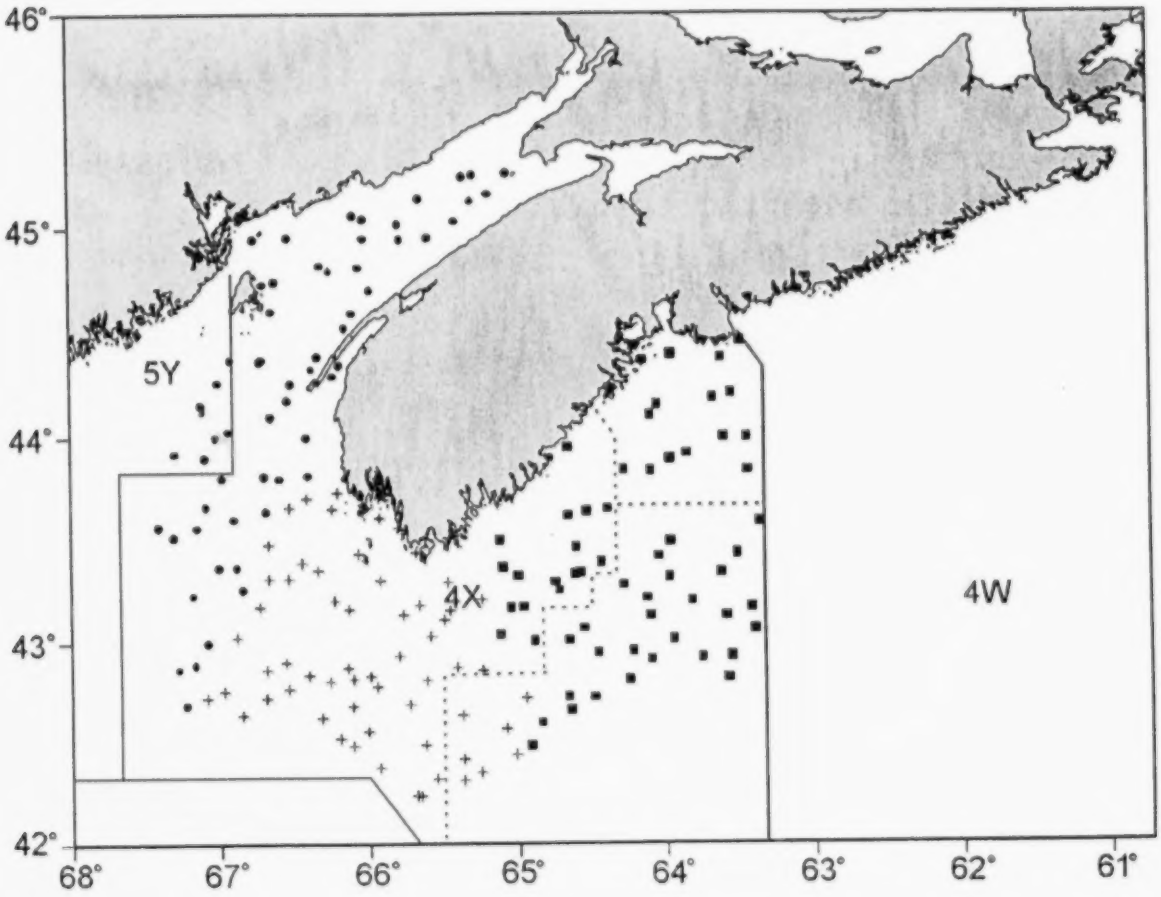



Fig. 18. ITQ survey area coverage and stations sampled by the three commercial fishing vessels in the Bay of Fundy (solid circle), Southwest Nova (plus sign), and Scotian Shelf (solid squares), 1996-2002.

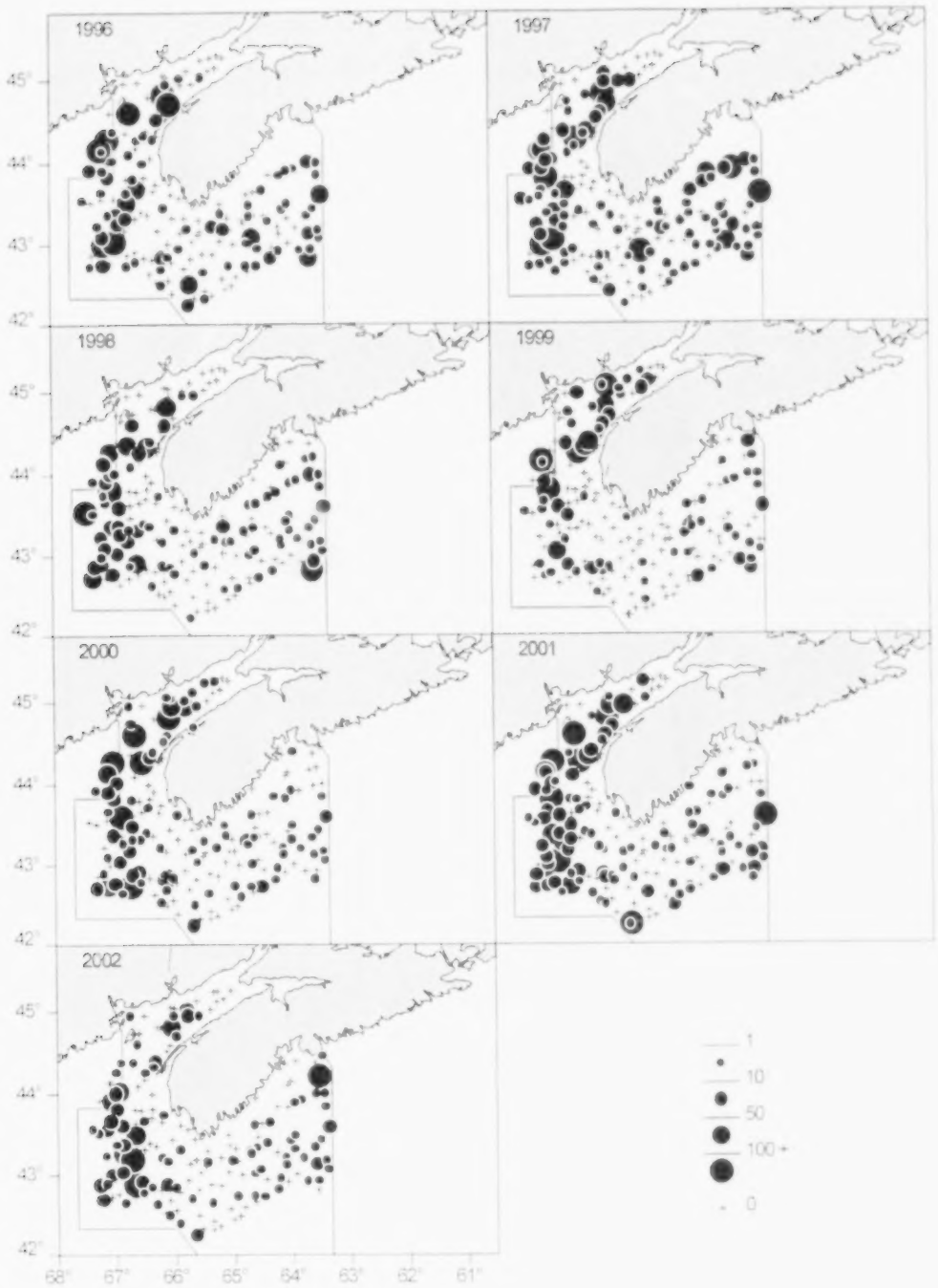



Fig. 19. Annual occurrence of pollock weight (kg) caught in the ITQ survey. All catches >100 kg are plotted by the same size symbol, decreasing the emphasis on large catches.

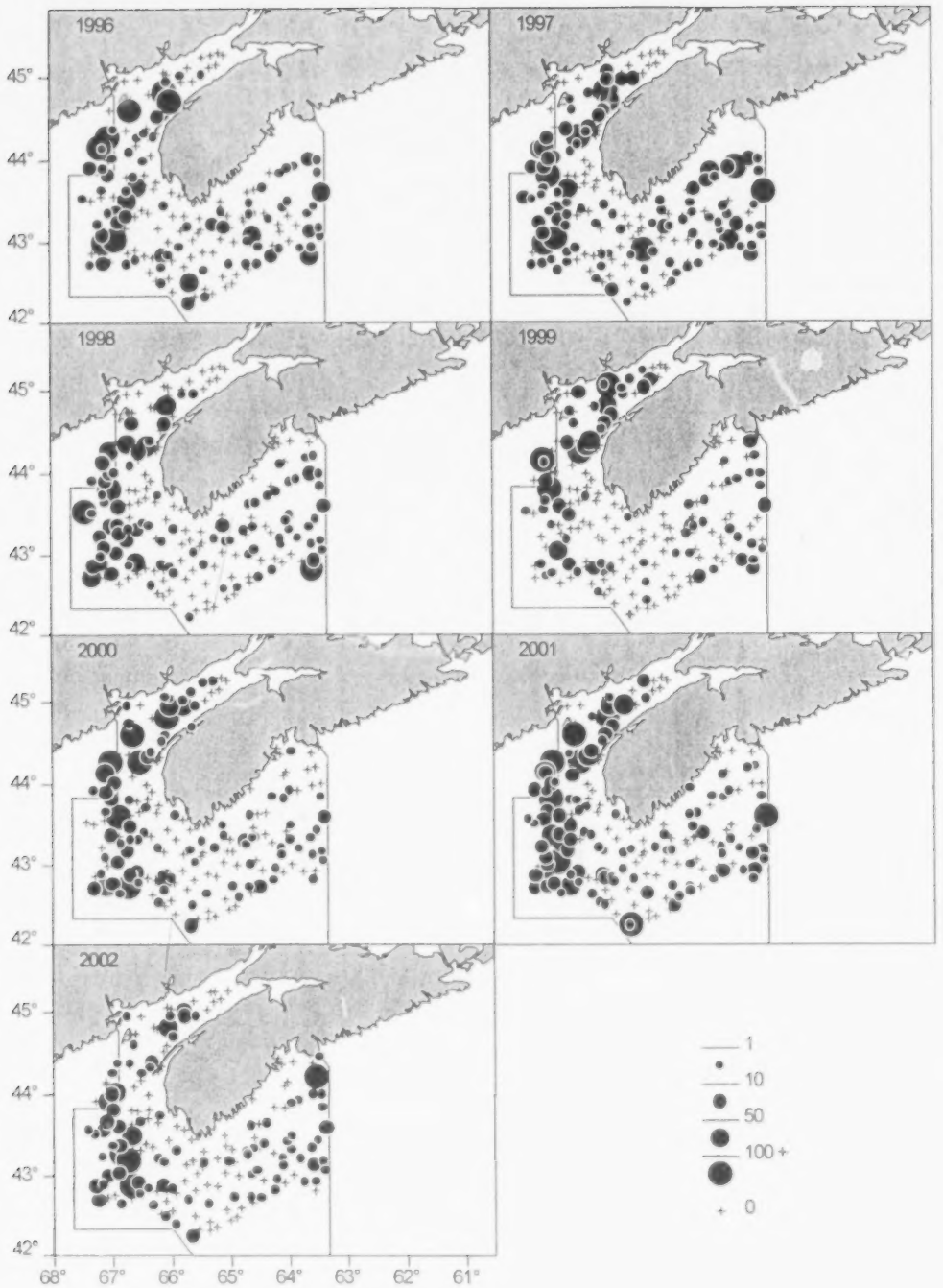



Fig. 19. Annual occurrence of pollock weight (kg) caught in the ITQ survey. All catches >100 kg are plotted by the same size symbol, decreasing the emphasis on large catches.

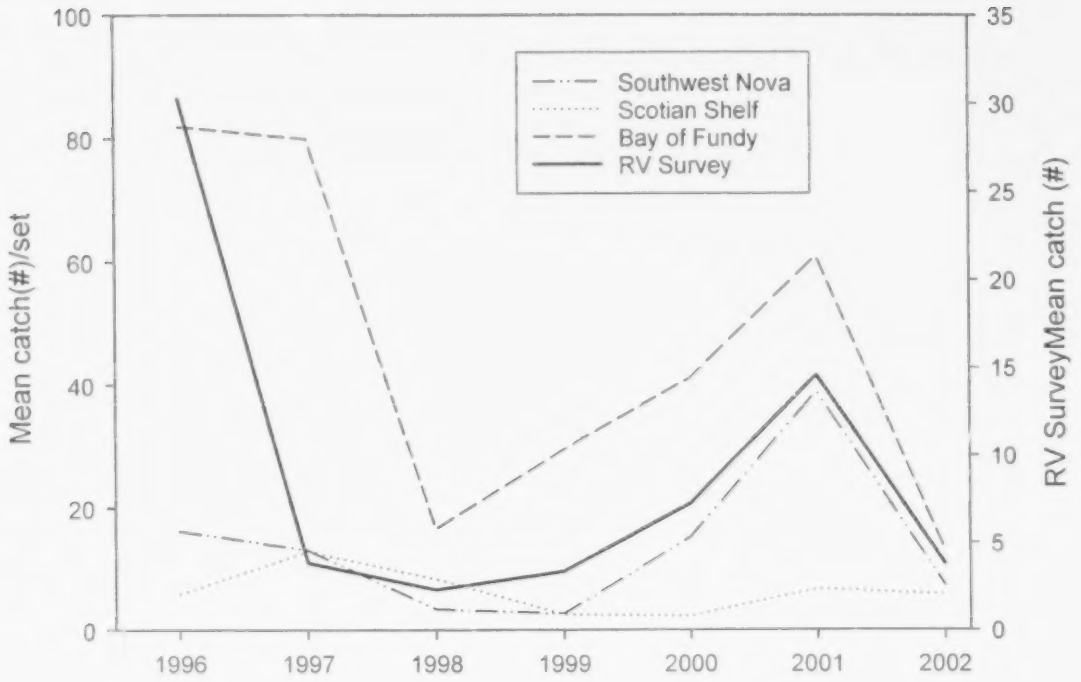



Fig. 20. Mean catch per set shown for the three vessels in the ITQ survey and compared with mean catches from RV summer groundfish surveys in 4Xopqrs.

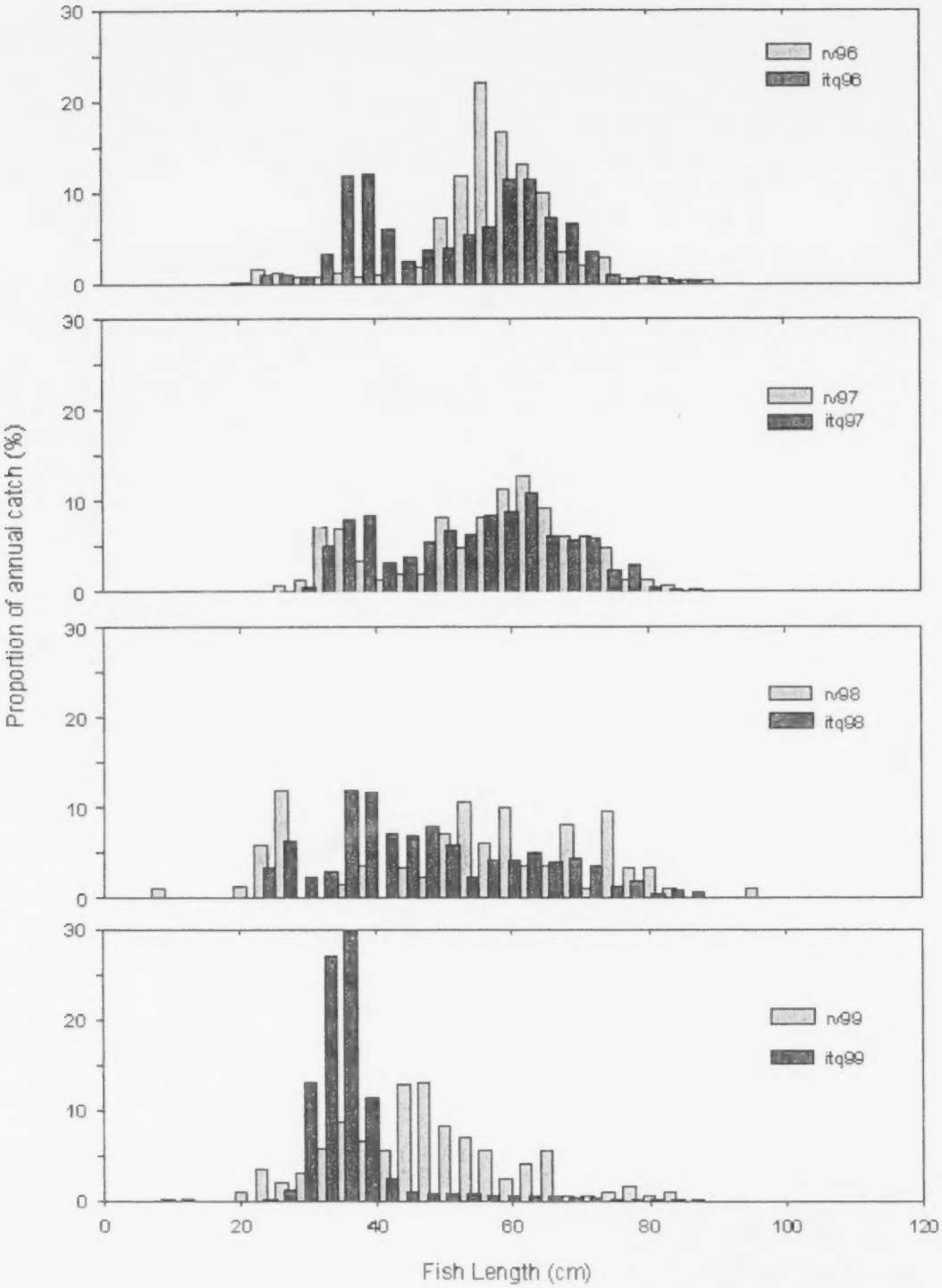



Fig. 21. Length frequency distributions from the ITQ surveys (dark grey) compared with RV summer groundfish surveys (light grey).

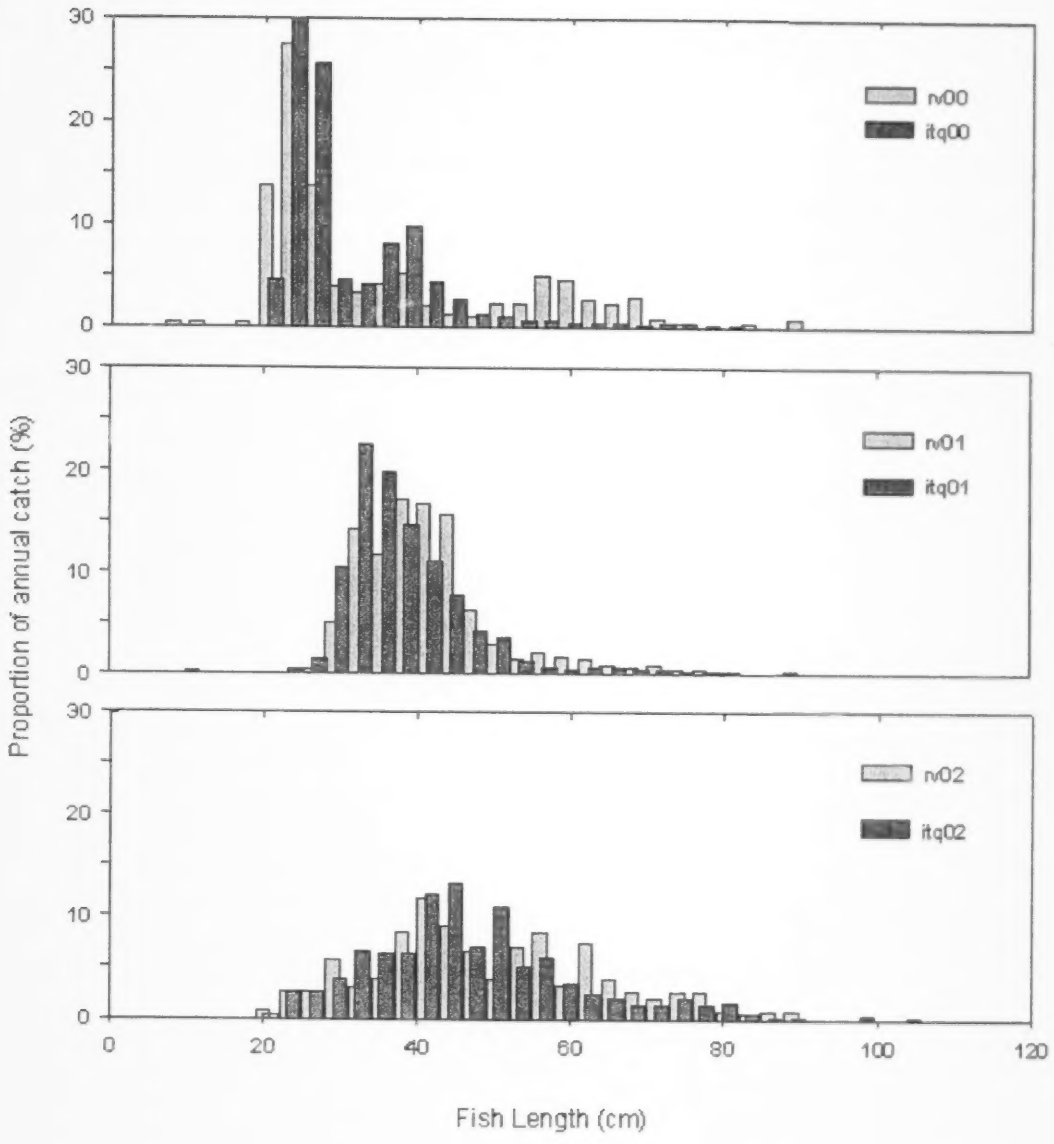



Fig. 21 (cont.). Length frequency distributions from the ITQ surveys (dark grey) compared with RV summer groundfish surveys (light grey).

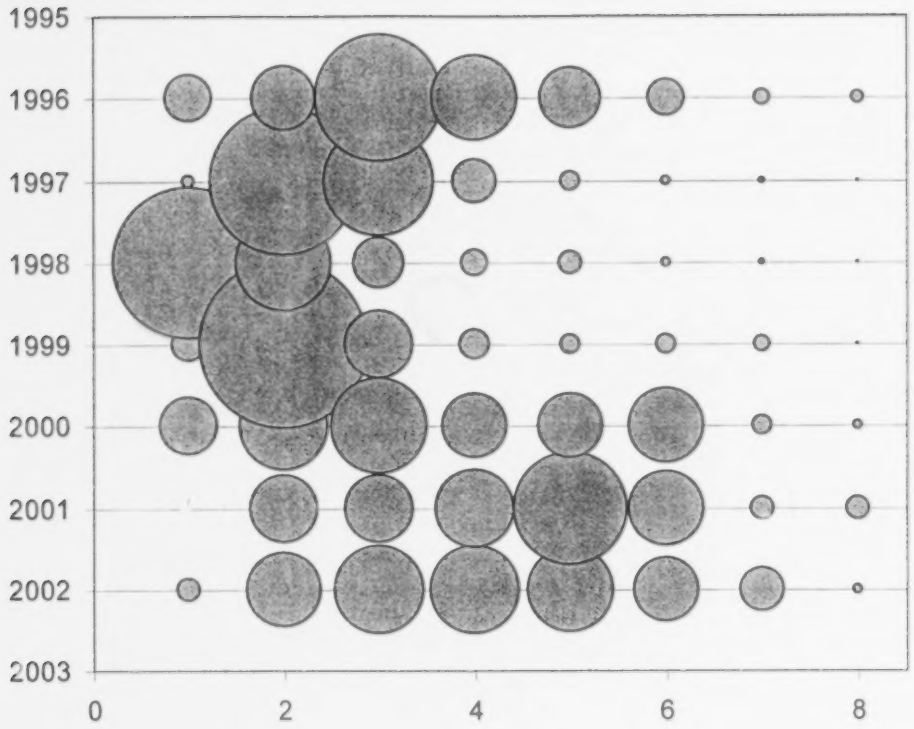



Fig. 22. Catch at age of pollock from ITQ surveys (1996-2002) from 4Xopqrs. Symbol size represents stratified mean catch at age, based on number caught, and is proportional to total annual catch.

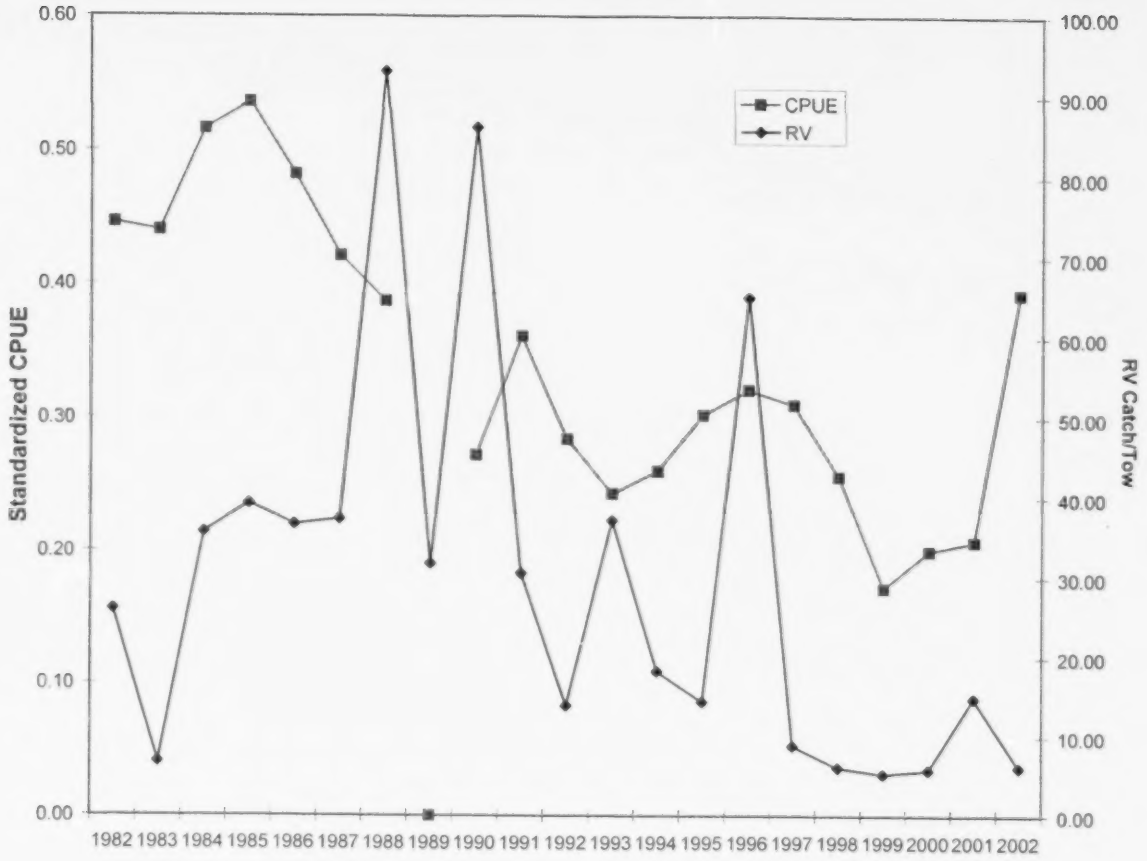



Fig. 23. Comparison of catch rates from DFO RV summer groundfish survey data and the commercial fishery for NAFO Unit Areas 4Xopqrs.

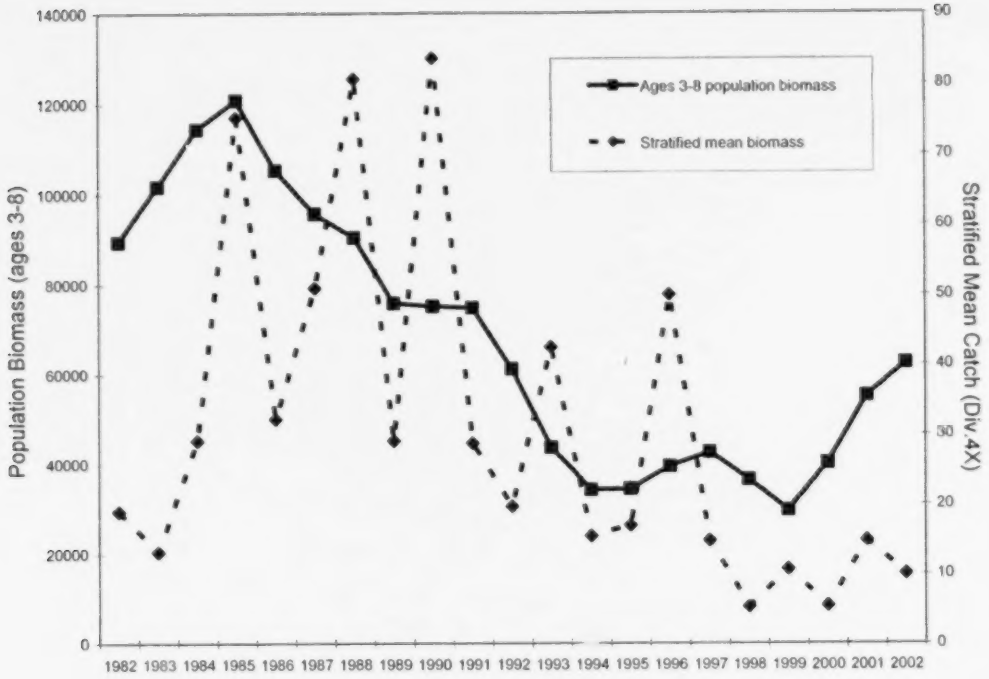



Fig. 24. Stratified mean weight of pollock from RV summer groundfish surveys in 4X compared with commercial data from 4X5Zc (ages 3-8 population biomass from the VPA). All sampling strata in 4X were used included for comparison with VPA output.